

June 1971

PB 202 345

Demonstration of a Regional Air Pollution Cost/Benefit Model

Environmental Protection Agency
Office of Air Programs
Washington, D.C.

Contract No. PH 22-68-60

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
Springfield, Va. 22151

APTD-0722

TRW
SYSTEMS GROUP

WASHINGTON OPERATIONS

292

BIBLIOGRAPHIC DATA SHEET	1. Report No. APTD-0722	2.	3. Recipient's Accession No.
	4. Title and Subtitle Demonstration of a Regional Air Pollution Cost/Benefit Model		5. Report Date June 1971
7. Author(s)		6.	
9. Performing Organization Name and Address TRW Systems Group 7600 Colshire Drive McLean, Virginia 22101		8. Performing Organization Rept. No.	
12. Sponsoring Organization Name and Address Environmental Protection Agency Office of Air Programs Research Triangle Park, North Carolina 27711		10. Project/Task/Work Unit No.	
		11. Contract/Grant No. PH 22-68-60	
		13. Type of Report & Period Covered	
		14.	
15. Supplementary Notes <u>DISCLAIMER</u> - This report was furnished to the Office of Air Programs by TRW Systems Group, 7600 Colshire Drive, McLean, Virginia 22101 in fulfillment of Contract No. PH 22-68-60			
16. Abstracts A program is presented which had as its objectives the design, assembly and delivery of analytic tools to be used in regional and national air pollution planning and management. The Cost/Benefit model described here completes a set of computer programmed air pollution analysis tools previously conceived. The completed project combines the results of systems analysis with cost/benefit analysis. A description is given of the programmed Benefits Model Segment, a user's manual, and the results of a study which was conducted to illustrate the operation characteristics of the Cost/Benefit Model. The various component modules of the Implementation Planning program and the Benefits model segment are presented. Also included is a presentation of the model demonstration in the National Capitol Interstate control region.			
17. Key Words and Document Analysis. 17a. Descriptors Air pollution Economic models Cost/benefit analysis Planning Regional planning Data acquisition Computer systems programs Computerized simulation			
17b. Identifiers/Open-Ended Terms Implementation Planning Program			
17c. COSATI Field/Group 13B, 5C			
18. Availability Statement Unlimited		19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 298
		20. Security Class (This Page) UNCLASSIFIED	22. Price

BLANK PAGE

DEMONSTRATION OF A REGIONAL
AIR POLLUTION COST/BENEFIT MODEL

July 1971

Prepared for
Environmental Protection Agency
Office of Air Programs

Contract No. PH 22-68-60

TRW SYSTEMS GROUP
7600 Colshire Drive,
McLean, Virginia 22101

The work upon which this
publication is based was performed
pursuant to Contract No. PH 22-68-60
with the Air Pollution Control Office,
Environmental Protection Agency.

TABLE OF CONTENTS

	<u>Page</u>
1.0 INTRODUCTION.	1
1.1 THE COST/BENEFIT MODEL.	1
1.2 COST/BENEFIT DESIGN AND DATA LIMITATIONS.	4
1.3 RESULTS OF COST/BENEFIT MODEL DEMONSTRATION	6
2.0 REGIONAL AIR POLLUTION ANALYSIS COST/BENEFIT MODEL.	9
2.1 GENERAL BACKGROUND AND OVERVIEW	9
2.1.1 Computer Simulation Modeling.	10
2.1.2 Air Pollution Cost/Benefit Analysis	13
2.1.3 Role of the RAPA Cost/Benefit Model in the Hierarchy of RAPA Analysis Tools.	13
2.1.4 RAPA Cost/Benefit Model, Program Overview	17
2.2 IMPLEMENTATION PLANNING PROGRAM	17
2.2.1 Component Programs of IPP	19
2.2.2 Point Source Cost Calculations in IPP	29
2.2.3 IPP Regional Strategies Output.	29
2.2.3.1 Tabulated Output for Cost/Benefit Analysis	29
2.2.3.2 Punched Card Output for Cost/Benefit Model.	34
2.3 CENSUS TRACT DATA	41
2.4 AIR POLLUTION DAMAGE FUNCTIONS.	44
2.4.1 Direct Damage Functions	44
2.4.2 Market Effects Damage Functions	50
2.5 INTERFACE MODULE.	52
2.5.1 Input	52
2.5.2 Analytical Technique for Estimating Census Tract Air Quality.	54

TABLE OF CONTENTS (Cont'd)

	<u>Page</u>
2.5.3 Output.	61
2.6 DAMAGE COSTS MODULE	62
2.6.1 Input	65
2.6.2 Output.	65
2.7 PROPERTY VALUE MODULE	68
2.7.1 Input	72
2.7.2 Output.	72
2.8 PROPERTY ASSIGNMENT MODULE.	76
2.8.1 Determination of Equilibrium Property Values in the Property Assignment Module.	79
2.8.2 Input	82
2.8.3 Output.	83
2.9 PROPOSED MODEL ADDITIONS.	85
3.0 MODEL DEMONSTRATION	87
3.1 INPUT DATA FOR THE NCIAQCR DEMONSTRATION.	87
3.1.1 Census Data	88
3.1.2 Pollutant Concentration/Strategy Data	88
3.2 ESTIMATION OF DIRECT DAMAGE COSTS	109
3.3 ESTIMATION OF PROPERTY VALUE EFFECTS.	113
4.0 REFERENCES.	119

APPENDICES

A THE IMPLEMENTATION PLANNING PROGRAM, CONTROL COST CALCULATIONS.	121
B SOURCES OF CENSUS TRACT INFORMATION REQUIRED FOR RAPA COST/BENEFIT MODEL	147
C PRO FORMA DAMAGE FUNCTION DEVELOPMENT	163
D DEMONSTRATION RESULTS TO THE POLITICAL JURISDICTION LEVEL	177
E USER'S MANUAL	203

FIGURES

	<u>Page</u>
1.1-1 Structure of the RAPA Cost/Benefit Model.	3
2.1-1 Computer Simulation Modeling.	11
2.1-2 Cost/Benefit Model in the Context of the RAPA Program	15
2.1-3 RAPA Cost/Benefit Model (Existing Version).	16
2.1-4 RAPA Cost/Benefit Model, Program Structure.	18
2.2-1 Structure of the Implementation Planning Program.	20
2.2-2 Role of Implementation Planning Program; RAPA Cost/Benefit Model.	21
2.2-3 Typical Emission Standard Curve Relation to Control Device Application.	25
2.2-4 Allowable Particulate Emissions Based on Industrial Process Weight (EST 19).	27
2.2-5 Output Format - Emission Standards Effects.	31
2.2-6 Output Format - Jurisdiction Summary.	32
2.2-7 Output Format - Control Strategy Summary.	35
2.2-8 Output Format - Ground Level Concentrations	36
2.2-9 Existing Ground Level Particulate Concentrations in the NCIAQCR as Computed by the Verified Air Pollutant Concentration Program	38
2.2-10 Predicted Particulate Concentrations After the Enactment of the Proposed Emission Control Strategy in all Political Jurisdictions	40
2.3-1 Population and Housing Data Relation to RAPA Cost/Benefit Model.	42
2.4-1 Damage Functions: Role in the RAPA Cost/Benefit Model	45
2.4-2 Wilson and Minnotte Function for Damages Due to Soiling . . .	46
2.4-3 Pro Forma Damage Functions Used in RAPA Cost/Benefit Model NCIAQCR Demonstration	48
2.5-1 RAPA Cost/Benefit Model; Interface Module	53

FIGURES (Cont'd)

	<u>Page</u>
2.5-2 RAPA Cost/Benefit Model; Receptor Point Census Tract Association.	55
2.5-3 Receptor Points Superimposed on Census Tracts of the NCIAQCR	56
2.5-4 Receptor Points Superimposed on Census Tracts of the NCIAQCR, Close-Up View of Central City.	57
2.5-5 Output Format - Tabulated Census Tract Pollutant Concentration Data.	62
2.6-1 RAPA Cost/Benefit Model; Damage Costs Module.	64
2.6-2 Sample Damage Costs Summary Output.	67
2.7-1 RAPA Cost/Benefit Model; Property Value Module.	69
2.7-2 Sample Output, Property Value Module.	74
2.8-1 RAPA Cost/Benefit Model; Property Value Assignment Module . .	77
2.8-2 Sample Output, Assignment Module.	84
3.1-1 List of Census Tract Attributes for the Washington, D. C. SMSA.	89
3.1-2 Existing Ground Level Particulate Concentrations in the NCIAQCR as Computed by the Verified Diffusion Model	104
3.1-3 Existing Ground Level Sulfur Dioxide Concentrations in the NCIAQCR as Computed by the Verified Diffusion Model . . .	106
3.2-1 Pro Forma Functions Utilized in NCIAQCR Cost/Benefit Demonstration	110
C.2-3 Pro Forma Damage Functions for SO ₂ and Particulates	175
E.1-1 Overall System Flow	204
E.3-1 Job Control Language and Deck Set-Up for Interface Module (CONVRT)	209
E.3-2 DRIVER for Interface Module - Program Listing	213
E.3-3 Input Data Form for Census Tract/Receptor Point Association	217

FIGURES (Cont'd)

	<u>Page</u>
E.3-4 Printed Input RPPC Data Summary, CØNVRT.	219
E.3-5 Printed Output CTPC Data Summary, CØNVRT	220
E.3-6 CØNVRT Subprogram, Interface Module-Program Listing.	221
E.3-7 Subroutine ØRDER, Interface Module-Program Listing	225
E.4-1 Job Control Language and Deck Set-Up for Damage Costs Module (DAMAGE).	228
E.4-2 Sample Output from Damage Costs Module, Title Page and Census Tract Attributes as Input	235
E.4-3 Sample Output from Damage Cost Module, Census Tract Pollutant Concentrations as Input.	236
E.4-4 Sample Output from Damage Costs Module, Census Tract Damage Cost Summary.	237
E.4-5 Program Listing for DRIVER Main Program - Damage Cost Module.	238
E.4-6 Program Listing for DAMAGE Subprogram - Damage Costs Module	239
E.5-1 Job Control Language and Deck Set-Up for Property Value Module.	247
E.5-2 Sample Output, Title Page and Census Tract Attributes Summary from Property Value Module	255
E.5-3 Sample Output, Census Tract Pollutant Concentrations (SO ₂ and Particulates) Summary from Property Value Module. .256	256
E.5-4 Sample Output, Census Tract Property Values Summary from Property Value Module	257
E.5-5 Program Listing for DRIVER, Main Program for Property Value Module.	258
E.5-6 Program Listing for Subprogram PRØP, Property Value Module .259	259
E.6-1 Job Control Language and Deck Set-Up for Assignment Module .269	269
E.6-2 Sample Output, Title Page and Census Tract Attributes - Assignment Module.	273
E.6-3 Sample Output, Census Tract Pollutant Concentration Summary (SO ₂ and Particulates) Assignment Module	274

FIGURES (Cont'd)

	<u>Page</u>
E.6-4 Sample Output, Census Tract Property Value Bids From Assignment Module.	275
E.6-5 Program Listing for DRIVER, Main Program for Assignment Module	276
E.6-6 Program Listing for ASSIGN Subprogram, Assignment Module	277

TABLES

		<u>Page</u>
2.2-1	Particulate Control Strategies - National Capital Interstate Air Quality Control Region.	39
2.4-1	Regression Results of Anderson-Crocker Study for the Washington, D. C. SMSA	51
3.1-1	Particulate and Sulfur Oxides Control Strategy Summaries - NCIAQCR.	108
3.2-1	NCIAQCR - Regional Damage Values Summary	111
3.3-1	Type I Property Values: NCIAQCR Regional Summary	115
3.3-2	Adjusted Type I Property Values: NICAQCR, Regional Summary.	116
A.2-1	Pollution Reduction Devices or Methods Applied to Point Sources in IPP.	123
A.2-2	IPP Control Device Preset Data	124
A.3-1	Fuel Parameters.	136
A.3-2	Boiler Efficiencies.	137
A.3-3	(f_1) Coal Particulate Emission Factors	138
A.3-4	(f_2) Oil and Gas Particulate Emission actors.	139
B.1-1	Census Tract Attributes, Notation and Definitions.	149
B.2-1	Sample Tables from the Censuses of Population and Housing with Annotations	153
B.3-1	List of NTIS Tapes of Population and Housing Data (1960 for the United States by Standard Location Area) . . .	161
C.2-1	Estimates of Nationwide Emissions, 1968.	166
C.2-2	National Total Annual Costs of Pollution for Types of Pollutants and Effects in 1968.. . . .	173
C.2-3	Coordinates for Damage Function Development.	174

TABLES (Cont'd)

	<u>Page</u>
D.1-1 NCIAQCR: Regional Damage Values Summary.	178
D.1-2 NCIAQCR: Damage Summary for Political Jurisdiction #1 - District of Columbia.	179
D.1-3 NCIAQCR: Damage Summary for Political Jurisdiction #2 - Montgomery County	180
D.1-4 NCIAQCR: Damage Summary for Political Jurisdiction #3 - Prince Georges County	181
D.1-5 NCIAQCR: Damage Summary for Political Jurisdiction #4 - Alexandria City	182
D.1-6 NCIAQCR: Damage Summary for Political Jurisdiction #5 - Arlington County.	183
D.1-7 NCIAQCR: Damage Summary for Political Jurisdiction #6 - Fairfax County.	184
D.1-8 NCIAQCR: Damage Summary for Political Jurisdiction #7 - Falls Church City	185
D.2-1 Type I Property Values: NCIAQCR Regional Summary	186
D.2-2 Type I Property Values: Political Jurisdiction 1, District of Columbia Summary.	187
D.2-3 Type I Property Values: Political Jurisdiction 2, Montgomery County, Md. Summary.	188
D.2-4 Type I Property Values: Political Jurisdiction 3, Prince Georges County, Md. Summary.	189
D.2-5 Type I Property Values: Political Jurisdiction 4, Alexandria, Virginia Summary.	190
D.2-6 Type I Property Values: Political Jurisdiction 5, Arlington County, Virginia Summary.	191
D.2-7 Type I Property Values: Political Jurisdiction 6, Fairfax County, Virginia Summary.	192
D.2-8 Type I Property Values: Political Jurisdiction 7, Falls Church, Virginia Summary.	193
D.3-1 Adjusted Type I Property Values: NCIAQCR, Regional Summary.	194

TABLES (Cont'd)

	<u>Page</u>
D.3-2 Adjusted Type I Property Values - Political Jurisdiction 1, District of Columbia.	195
D.3-3 Adjusted Type I Property Values - Political Jurisdiction 2, Montgomery County	196
D.3-4 Adjusted Type I Property Values - Political Jurisdiction 3, Prince Georges County	197
D.3-5 Adjusted Type I Property Values - Political Jurisdiction 4, Alexandria.	198
D.3-6 Adjusted Type I Property Values - Political Jurisdiction 5, Arlington County.	199
D.3-7 Adjusted Type I Property Values - Political Jurisdiction 6, Fairfax County.	200
D.3-8 Adjusted Type I Property Values - Political Jurisdiction 7, Falls Church.	201
E.2-1 Format Information for Census Tract Attribute Data Cards. . .	206
E.3-1 Formats for Transform Data Cards.	211
E.3-2 Receptor Air Quality Data Card Formats.	215
E.3-3 Census Tract Pollutant Concentration Output Data Formats. . .	218
E.4-1 Damage Function Slope and Intercept, Input Data Format - Damage Costs Module	231
E.4-2 Census Tract Attributes as Read by DAMAGE	232
E.4-3 Census Tract Air Quality Data Formats for SO ₂ or Particulates, Damage Costs Module	233
E.5-1 Sulfation Rate and Regression Coefficient Input Data Formats, Property Value Module.	250
E.5-2 Census Tract Attribute Data Formats as Read by the Property Value and Assignment Modules	251
E.5-3 Census Tract Air Quality Input Data Formats for SO ₂ , Property Value and Assignment Modules	252
E.5-4 Census Tract Air Quality Input Data Formats for Particulates, Property Value and Assignment Module.	253

TABLES (Cont'd)

	<u>Page</u>
E.6-1 Assignment Module Input Format for Regression Coefficients (Type I).	270
E.6-2 Census Tract Attribute Data Formats as Read by Assignment Module	271

1.0 INTRODUCTION

The RAPA Cost/Benefit Model which is the subject of this report represents the last major computer program to be developed under the three-year Regional Air Pollution Analysis (RAPA) contract at TRW Systems Group. Appropriately, it also provides the last basic link in the chain of computer programmed air pollution analysis tools that were originally conceptualized during the first phase of the contract.

This report serves two major purposes: (1) it offers a program description and user's manual for the RAPA Cost/Benefit Model; (2) it presents the results of a demonstration cost/benefit analysis for the National Capital Interstate Air Quality Control Region.

1.1 THE COST/BENEFIT MODEL

The aim of cost/benefit analysis is to maximize the present value of all benefits less that of all costs incurred, subject to specified constraints. Cost/benefit analysis has been considered for use in the evaluation of transportation systems, criminal rehabilitation programs, urban renewal projects, and other social programs.

In air pollution control, cost/benefit analysis can be employed to compare the social costs and benefits resulting from a potential air resource management policy with those to be expected from a continuation of the existing level of effort (the "base alternative"). After defining the project life (the period of time over which costs and benefits will be measured), the costs and benefits of alternative air resource policies are computed and discounted back to the base year for purposes of comparative analysis. The resulting data may then be used in the evaluation of alternative policies.

An integration of economics, cost/benefit and systems analysis procedures is necessary to analytically evaluate the air resource problem. Such a combination of techniques provides a consistent methodology for integrating the quantitative results of research into the air resource planning and decision-making process.

The RAPA Cost/Benefit Model combines the system analysis techniques of the Implementation Planning Program (IPP) with the economic relationships of the Benefit Model.

The IPP, which is one of the chain of RAPA models, was developed earlier and is an integral part of the C/B Model. It provides two major outputs: (1) the regional air quality display; and (2) point source control costs. The Benefits Model Segment accepts as an input from the IPP the regional air quality display and, through the application of receptor data and damage functions, produces damage cost estimates as output.

The relationship between IPP and the Benefits Model Segment is presented in Figure 1.1-1. Notice that the control cost estimates are provided directly from printouts of the IPP, whereas, the damage cost estimates are printouts of the Benefits Model Segment. The types of available information and the printout formats for the IPP and the Benefits Model Segment are reported in this document. The two separate outputs require the analysts to combine the control and damage cost estimates and provide an interpretation consistent with conventional cost/benefit analysis procedures.

The Cost/Benefit Model is a cross-sectional model (i.e., air pollution control strategies are evaluated at one instantaneous point in time). This means that the Model must be applied in annual intervals over the length of

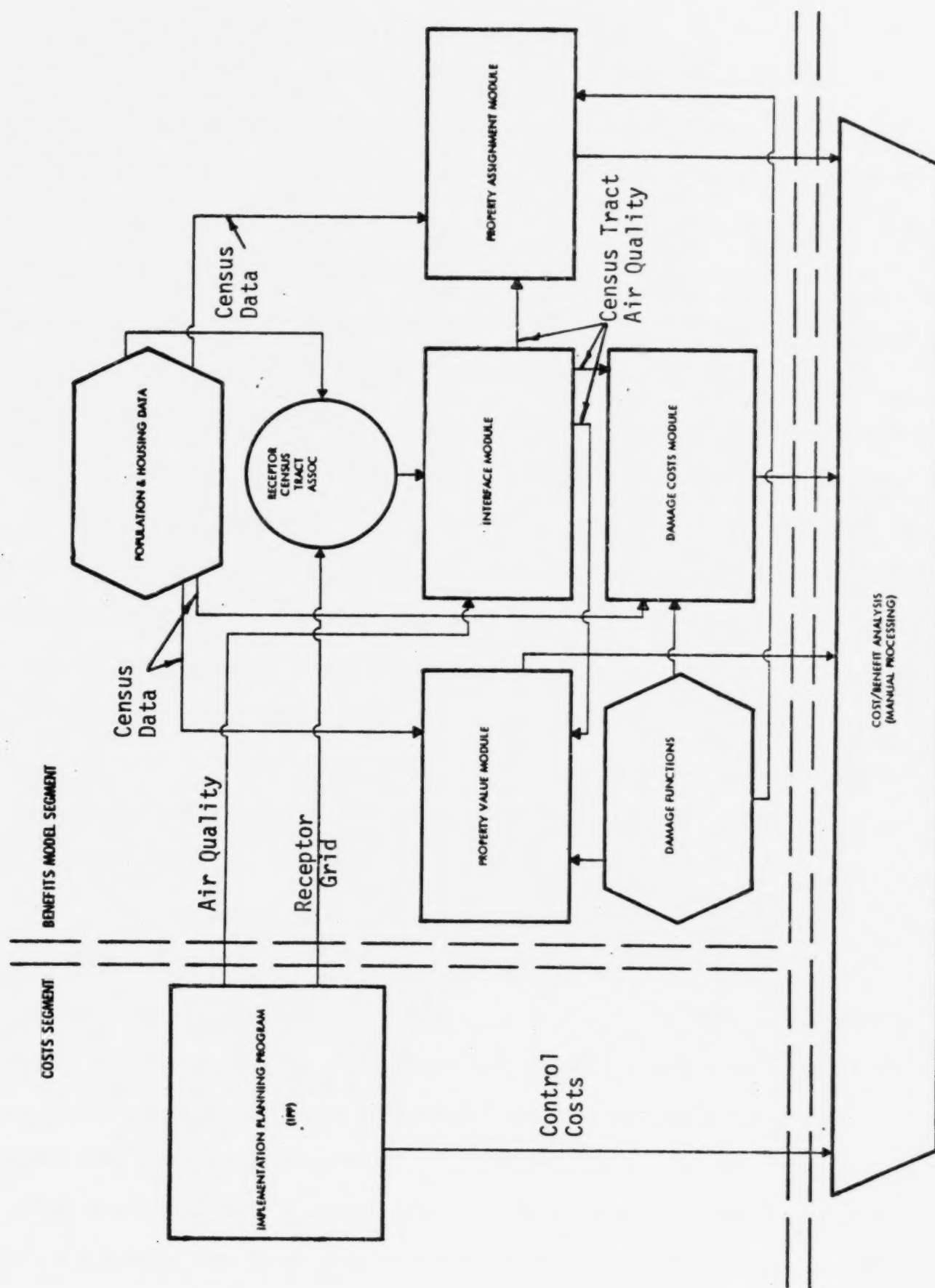


Figure 1.1-1. Structure of the RAPA Cost/Benefit Model.

the project life if conventional cost/benefit analyses are to be conducted. After estimating the control costs and benefits of control strategies over time, they can then be discounted back to the current years before the benefit/cost relationships of alternative strategies are evaluated for decision-making purposes.

The major portion of this document is devoted to the description of the software of the Benefits Model Segment. As shown in Figure 1.1-1, the Model relates the predicted pollution concentration (i.e., air quality display) to receptor data and damage functions. The exposure of receptors to pollutants (a measure of "dosage") is determined by the air quality-receptor relationship. The damage function (which relates the annual cost of air pollution damage to pollution concentration) when applied to the dosage estimate, determines the damage cost estimate desired. Estimates of benefits (i.e., a reduction in damages) are calculated by subtracting damage estimates for alternative strategies from the damages caused by existing atmospheric conditions.

The design philosophy of the Cost/Benefit Model has been based on the use of data which are either readily available or which are identifiable and capable of being collected within a reasonable period of time. The models are thus practical devices which use the best decision-making information available.

1.2 COST/BENEFIT DESIGN AND DATA LIMITATIONS

There are three fundamental limitations in the structure of the Cost/Benefit Model. First, the Model is essentially static in that costs and benefits are treated as scalar current values rather than streams of future costs and benefits to be realized as control is continuously applied and as a region undergoes social and economic change. Forecasting

capabilities would be desirable in the Model to predict the future emission potential, distribution of receptors, technological changes, land-use plans, etc. Second, the Model treats pollutants individually. That is, cost/benefit comparisons are made on the basis of one pollutant at a time, neglecting effects which levels and control measures for other pollutants may have on the benefits and control costs for the pollutant under consideration. Selection of a truly efficient strategy requires that the Model be capable of simultaneous evaluation of strategies for all pollutants. Third, the Model is limited to only two pollutants primarily because of the use of a long-term-average diffusion segment. Transportation planning, land-use planning, power plant siting and other strategies may be incorrectly evaluated if pollutants such as carbon monoxide, hydrocarbons, nitrogen oxides, and others are ignored. The investigation of integrating other atmospheric diffusion models into the Cost/Benefit Model appears worthwhile.

Besides limitations in the Model structure, there are also a number of restrictions regarding data inputs to the system. As the Model now stands, control costs and benefits are accounted for only partially. The only control costs currently included in the Model are point source control costs (i.e., no account has been taken of area source costs or control agency costs). Area source costs for a region are likely to be substantial, and will include the cost of reducing emissions from: (1) the incineration of solid waste not disposed of in municipal incinerators; (2) residential, commercial and institutional fuel combustion; (3) mobile sources; and (4) small industrial process sources. Control agency costs have often been considered small relative to other control costs, but may represent fifteen percent or more of the total regional cost of reduced emissions. Accounting for control agency costs may be important when strategies based on totally

different principles are evaluated and compared. An example may be the comparison of the current system of direct regulations to a system of emission charges.

Finally, probably the greatest deficiencies in the Model are caused by the lack of acceptable damage functions. Damage functions relate one's "willingness-to-pay" to avoid air pollution (i.e., the social value of cleaning up the atmosphere) to the pollution concentration to which a person or thing is exposed. Such relationships are difficult to develop, and documented results regarding the economic effects of air pollution on health, materials, vegetation, soiling, esthetics, and residential property values are just now becoming available. To be compatible with the requirements of the Model, this data must be transformed into the damage function form. For now, even without damage functions, the C/B Model can be used for "exposure" studies since knowledge of the relationship between pollutant concentration and receptors is by itself valuable for decision-making.

1.3 RESULTS OF COST/BENEFIT MODEL DEMONSTRATION

The specifications for the Cost/Benefit Model described in the previous section were developed and presented in a previous RAPA report [Woodcock, 1971]. This document presents a description of the programmed Benefits Model Segment, a user's manual, and the results of a study which was conducted to illustrate the operation characteristics of the Cost/Benefit Model.

The various component modules of the Implementation Planning Program (IPP) and the Benefits Model Segment (including the input data, output data, analytical procedures and output formats, etc.) are presented in Chapter 2.0.

A presentation of the Model demonstration in the National Capital Interstate Air Quality Control Region (NCIAQCR) is presented in Chapter 3.0 of this document. Included in the presentation are the control costs and air quality impacts of the alternative control strategies which were considered in the demonstration, and the benefits which accrue as each of these control strategies is applied to the region based on (a) the Pro Forma Damage Function, and (b) the Property Value impact before and after establishment of market equilibrium. The Washington region was selected because of the availability of an extensive analysis of alternative control strategies which was done as a part of the preparation of the Washington AQCR Implementation Plan. These demonstration results provide source data which can be used as the basis for an analysis of the cost/benefit impact of these alternative control strategies. This effort was only a portion of the RAPA Phase III activity and the contract resources did not permit a sufficiently complete interpretation of the results. Consequently, no analysis of the results is presented: a forthcoming Office of Air Programs report will cover this subject.

BLANK PAGE

2.0 REGIONAL AIR POLLUTION ANALYSIS COST/BENEFIT MODEL

2.1 GENERAL BACKGROUND AND OVERVIEW

The National and Regional Air Pollution Systems Analysis Program, contracted to TRW by DHEW in July 1968, had as its objectives the design, assembly and delivery of analytic tools to be used in regional and national air pollution planning and management. The view at the time was that the regional and national aspects of the air pollution problem required similar analytical processes and data. Computer programs were to be developed which would give decision-makers a means of determining the most effective tactics and strategies for both the national and regional control efforts. The overlapping of the national and regional data and analysis requirements would minimize the development cost.

The RAPA Cost/Benefit Model completes the set of computer programmed air pollution analysis tools conceived early in the history of the contract. The completed cost/benefit project combines the results of systems analysis with cost/benefit analysis; the combination of techniques provides a consistent methodology for integrating the quantitative results of research into the air resource planning and decision process. This integration is accomplished by interpreting the results of different research efforts on a common economic scale.

The systems analysis techniques employed in regional air pollution analysis involve computer simulation modeling of the regional air pollution control process. This is accomplished through the Implementation Planning Program, an earlier "link" in the RAPA chain of models. The cost/benefit analysis is accomplished through the component programs and modules of the RAPA Cost/Benefit Analysis Model. The basic concepts of deterministic computer simulation analysis and cost/benefit analysis are discussed below.

2.1.1 Computer Simulation Modeling

The concept of computer simulation modeling, represented in Figure 2.1-1 is based on the use of mathematical models to simulate the behavior of real physical phenomena. Usually, these phenomena are too complex to simulate directly. In such cases, the mathematical models actually represent theoretical models which are idealizations or approximations of the actual phenomena.

A mathematical model is one or more empirical or theoretical equations (or inequalities) which translate a real system (physical, economic, etc.) into a numerical representation. In the case of air pollution control, the real-world system includes such aspects as pollution sources, atmospheric processes, receptors, and pollution control techniques. All of these are elements in a system. The mathematical models describe the relevant features of each element, as well as the relationships between elements. For example, equations are provided for the characteristics of control devices and for the relationships between the application of a control device and the resulting ground-level concentration at a specified receptor location.

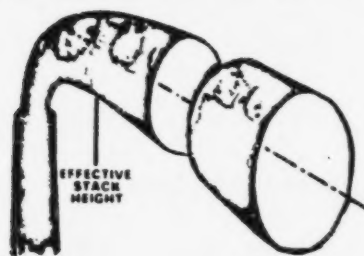
The mathematical models are then incorporated into a mathematical simulation which describes an algorithm or procedure for executing the models under prescribed conditions. For air resource applications, these conditions include given meteorological situations, certain industrial process rates, etc. The execution of the model results in a time or event history of responses for each model individually or for the entire system of interrelated models; this process is a mathematical simulation of a system described by mathematical models. If the mathematical models are executed according to the instructions contained in a computer program, then the mathematical simulation is referred to as a computer simulation or computer simulation model.

REAL WORLD PHENOMENON



POINT SOURCE

THEORETICAL MODEL



MATHEMATICAL SIMULATION

$$X = \frac{Q}{\pi u \sigma_z \sigma_y} \exp\left(-\frac{H^2}{\sigma_z^2}\right)$$

COMPUTER SIMULATION

TABLE 1.1

SAMPLE CALCULATIONS				
SAMPLE NO.	LOCATION		CALCULATED CONCENTRATION	
	X (m)	Y (m)	CONCENTRATION (mg/m³)	CONCENTRATION (µg/m³)
1	100	0	1.0	1.0
2	200	0	0.5	0.5
3	300	0	0.3	0.3
4	400	0	0.2	0.2
5	500	0	0.15	0.15
6	600	0	0.1	0.1
7	700	0	0.08	0.08
8	800	0	0.06	0.06
9	900	0	0.05	0.05
10	1000	0	0.04	0.04

Figure 2.1-1. Computer Simulation Modeling

Normally, the results of a computer simulation are first used in a comparison with actual results of observations of the real system under conditions similar to those in the simulation. In the case of an air pollution control simulation, these observations include measurements of air quality at various locations. If the computer simulation results reasonably approximate the actual observations, then the simulation is said to be verified. A verified computer simulation implies a degree of confidence in the computer program's ability to simulate the real system. Based on this degree of confidence, the simulation can be used to predict the behavior of the real system under conditions for which observations are not available. However, care must be exercised, in employing the computer simulation to predict the behavior of the system under circumstances far from those involved in the verification process.

The enormous data-handling capabilities of digital computers and the programmed ability to step through complex sets of relationships have made the computer simulation solution an indispensable tool in the study of large-scale complex systems problems. With the development of accurate models and reliable simulations, the user can get a measure of the cost and effectiveness of various alternatives. These alternatives can then be ranked in order according to their desirability against prescribed criteria for specific objectives.

2.1.2 Air Pollution Cost/Benefit Analysis

The formal theory of cost/benefit analysis requires that the costs and benefits of a proposed project or policy be: (1) measured relative to some base-line (i.e., initial time and conditions) and (2) evaluated over a definite period of time (e.g., project life-time).

The existing version of the RAPA Cost/Benefit Model as well as all the other components of the RAPA Program assume that all system responses of interest occur instantaneously. Consequently, the Cost/Benefit Model represents a special limited version of cost benefit analysis, known as cross-sectional modeling. In the cross-sectional cost/benefit model, the base-line or initial conditions are first analyzed, then assuming that all responses are instantaneous, the effects of alternative policies are evaluated. The benefits are based on more than one parameter (e.g., air quality, population, income, etc.) and the relations may be deduced from a statistical analysis on the different parameters. At the present time, the inability to provide forecasts for the future concerning the availability and demand for fuel, price structures, industrial process developments and control technology advances make the cross-sectional approach the practical state of the art.

2.1.3 Role of the RAPA Cost/Benefit Model In The Hierarchy of RAPA Analysis Tools

The first production computer program of the Regional Air Pollution Analysis (RAPA) Program was the Air Quality Display Model [TRW, November 1969]. This program employs a mathematical simulation of the atmospheric diffusion process [Martin and Tikvart, 1968] to determine estimated arithmetic average pollutant concentrations at ground level over an annual period. It also contains a statistical model [Larsen, 1969] which produces geometric-mean and maximum concentration values for several different averaging times.

In July 1969, at the conclusion of the first year's efforts (Phase I), TRW demonstrated the operation of a prototype Regional Air Pollution Analysis Program using the St. Louis Air Quality Control Region as the data base.

The diffusion and statistical models of AQDM provided a key module for the more ambitious Implementation Planning Program, the initial version of which (IPP I) was ready in March 1970. The production version of the Implementation Planning Program (IPP II) was published in November 1970 and is described at some length in Section 2.2. It was actually the prototype IPP I, however, which provided the critical interface with the RAPA Cost/Benefit Model for the current demonstration, since shakedown runs were still underway for IPP II during the programming phase of the RAPA Cost/Benefit Model [TRW, November 1970].

The current prototype Cost/Benefit Model, produced as part of the Phase III RAPA effort, provides another basic block for the general RAPA Program. A series of economic models have also been developed by the CONSAD Research Corporation under sub-contract to TRW. The relation of all these computer programs to one another in the existing concept of the RAPA Program is illustrated in Figure 2.1-2. The prototype RAPA Cost/Benefit Model (illustrated in Figure 2.1-3) represents a partial development of the concept illustrated in Figure 2.1-2.

The Benefits Model Segment consists of an Interface Module and three analysis modules (Damage Cost Module, Property Value Module, Property Assignment Module). The Interface Module converts receptor point air quality data (provided by the Implementation Planning Program) into census tract (average) air quality. The Implementation Planning Program also serves as the Costs Segment of the prototype Cost/Benefit Model; only the direct point sources control costs are included in the analysis at the present time.

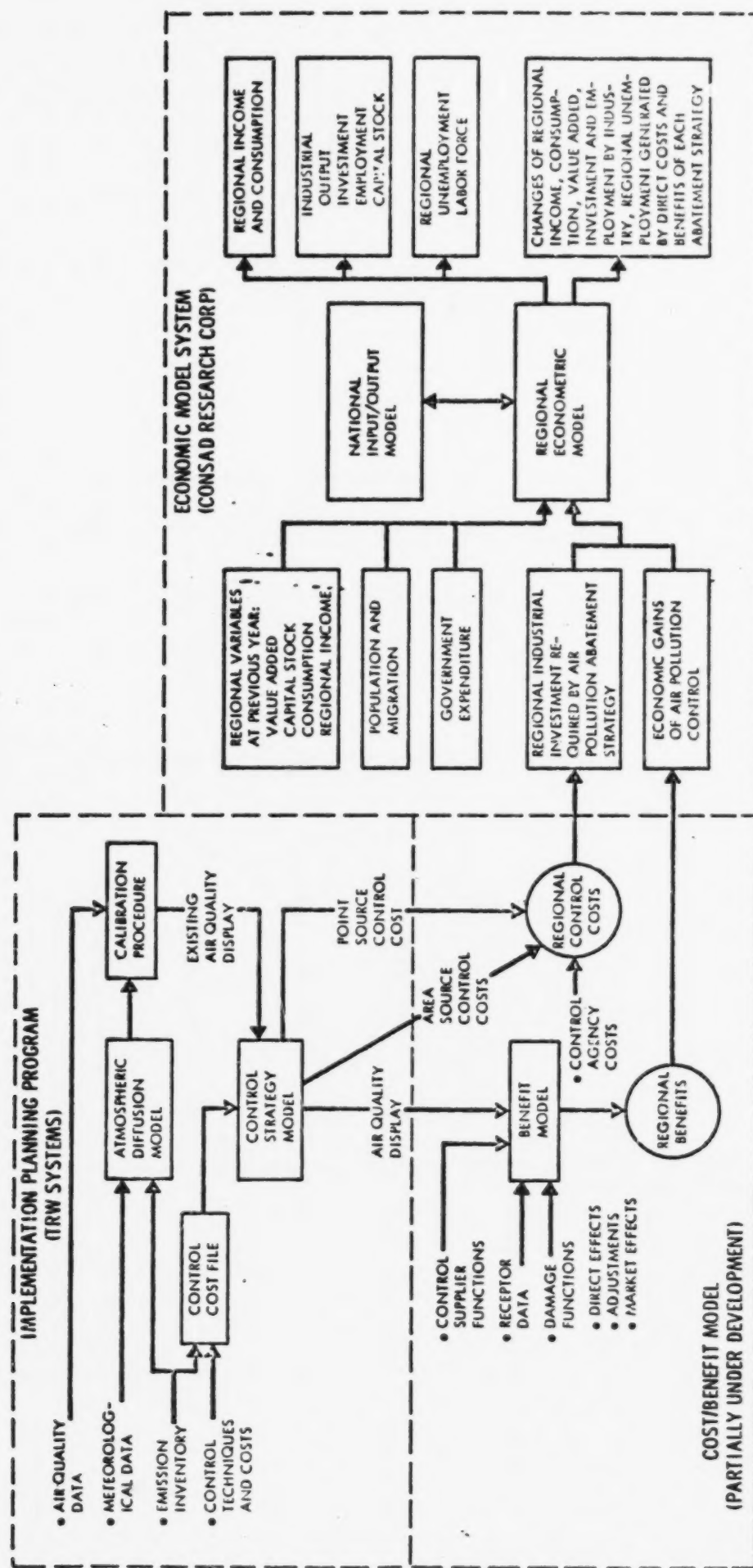


Figure 2.1-2. Cost/Benefit Model In The Context Of The RAPA Program.

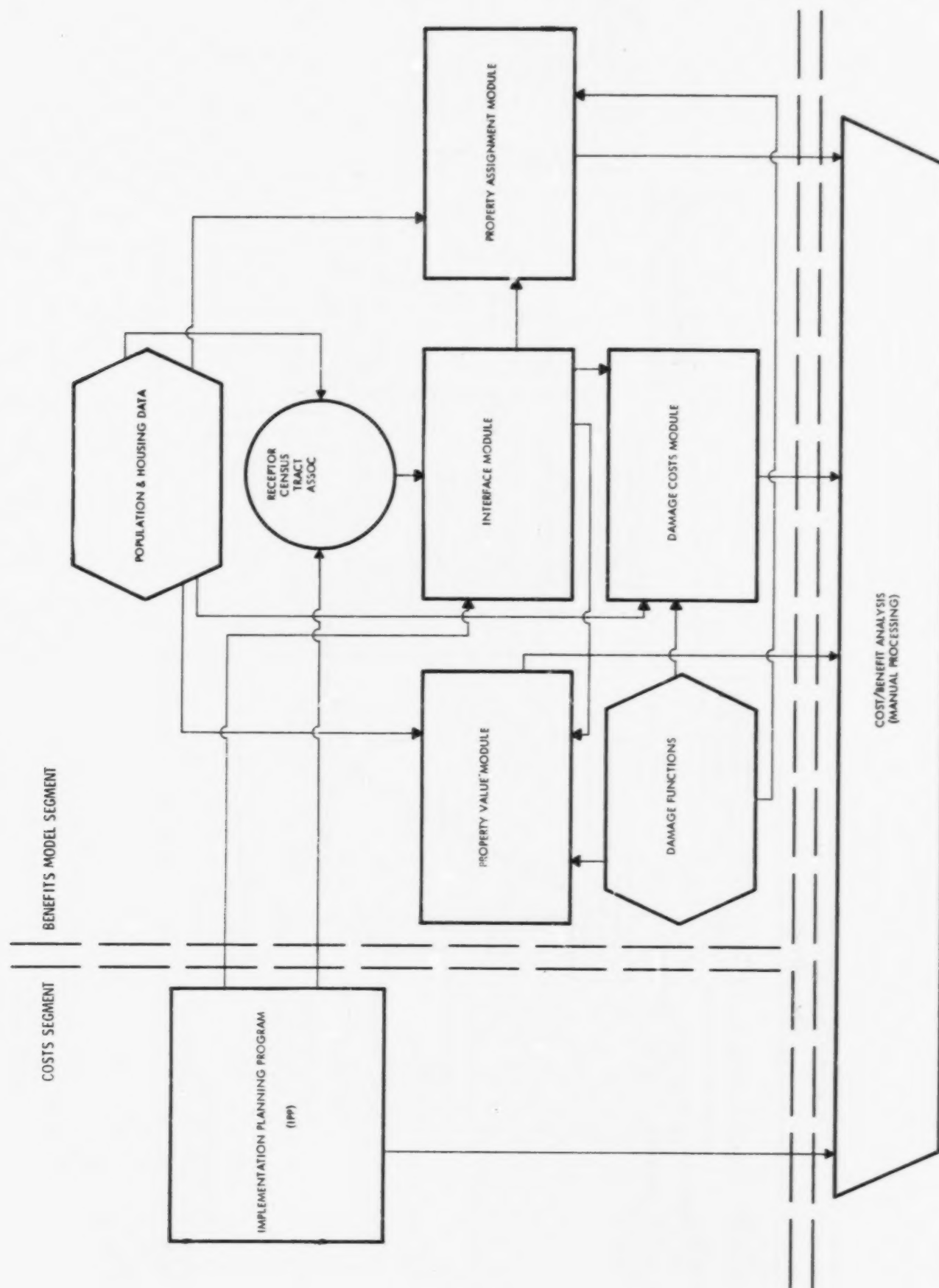


Figure 2.1-3. RAPA Cost/Benefit Model (Existing Version)

2.1.4 RAPA Cost/Benefit Model, Program Overview

The computer program modules which comprise the RAPA Cost/Benefit Model process population and housing census information along with pollutant concentration data. The resulting information output supports air resource cost/benefit analysis procedures.

Figure 2.1-4 illustrates the various modules of the C/B Model, their principal inputs and outputs, and the interfaces between the modules. As shown by the figure, the program modules of the C/B Model do not function together in a fully integrated system as do the programs and program segments of IPP illustrated in Figure 2.1-2. Rather, these modules are essentially independent; each supports a specific cost/benefit analysis procedure. They are linked by a common data set (shown as a card deck in Figure 2.1-4) of census tract attributes (population and property), and a common interface module (CONVRT) which supplies the census tract pollutant concentration data. This modular character of the RAPA C/B Model permits easy modification of existing capabilities and aids future expansion of the model through addition of new modules.

2.2 IMPLEMENTATION PLANNING PROGRAM

The Implementation Planning Program (IPP) is a collection of computer programs which have been developed for the Environmental Protection Agency for use by the states (Federal Register, Vol. 36, No. 67, Part II, April 7, 1971) as an analytical tool to assist in the preparation of implementation plans* for sulfur oxides and particulates. Through the application of

*An implementation plan details all the steps to be taken for abatement and control of emissions from existing sources of pollutants within an air quality control region, to insure attainment of the ambient air quality standards within a reasonable time.

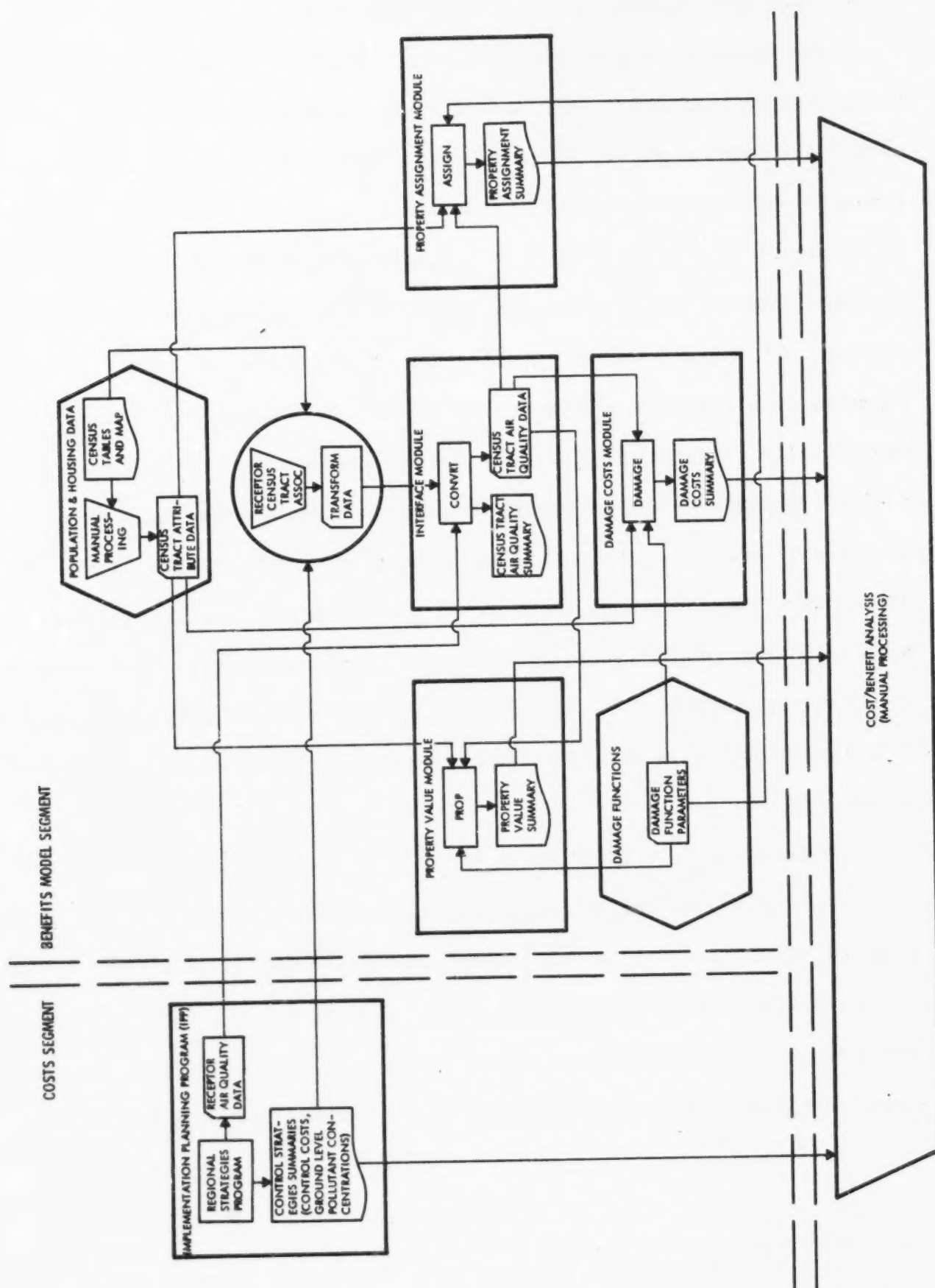


Figure 2.1-4. RAPA Cost/Benefit Model, Program Structure.

of computer simulation modeling techniques, the Implementation Planning Program is used in selecting appropriate emission standards, evaluating the resulting air quality, and determining the costs associated with the various alternative control strategies.

2.2.1 Component Programs of IPP

The distinct computer programs which comprise IPP are designed to run in sequence, as shown in Figure 2.2-1. The function of each program is described below in the order of the program's normal operating sequence in IPP. The role of IPP in the RAPA Cost/Benefit Model is shown (see the shaded portion) in Figure 2.2.2.

(1) Source Data Management Program. This program creates, updates, and lists the primary data file (defined as the Source File). The Source File contains all the sources of pollutants in a given Air Quality Control Region which are to be considered by the Implementation Program. These sources of pollutants are divided into categories of point and area sources. A point source of emission is defined here as any individual stationary source for which specific information is input to the program, and is usually specified on the basis of a single stack. An area source includes the total emissions from all sources within a given square area which are either too small or too numerous to specify on an individual point source basis. The total emissions for an area source are assumed to be uniformly distributed over the area. Area sources generally include small fuel combustion sources, on-site solid waste disposal, mobile sources, etc. Data on area sources are included in determining the ground level pollution concentration values.

The Source File itself provides direct input to the Air Pollutant Concentration Program, the Control Cost Program and the Regional Strategies

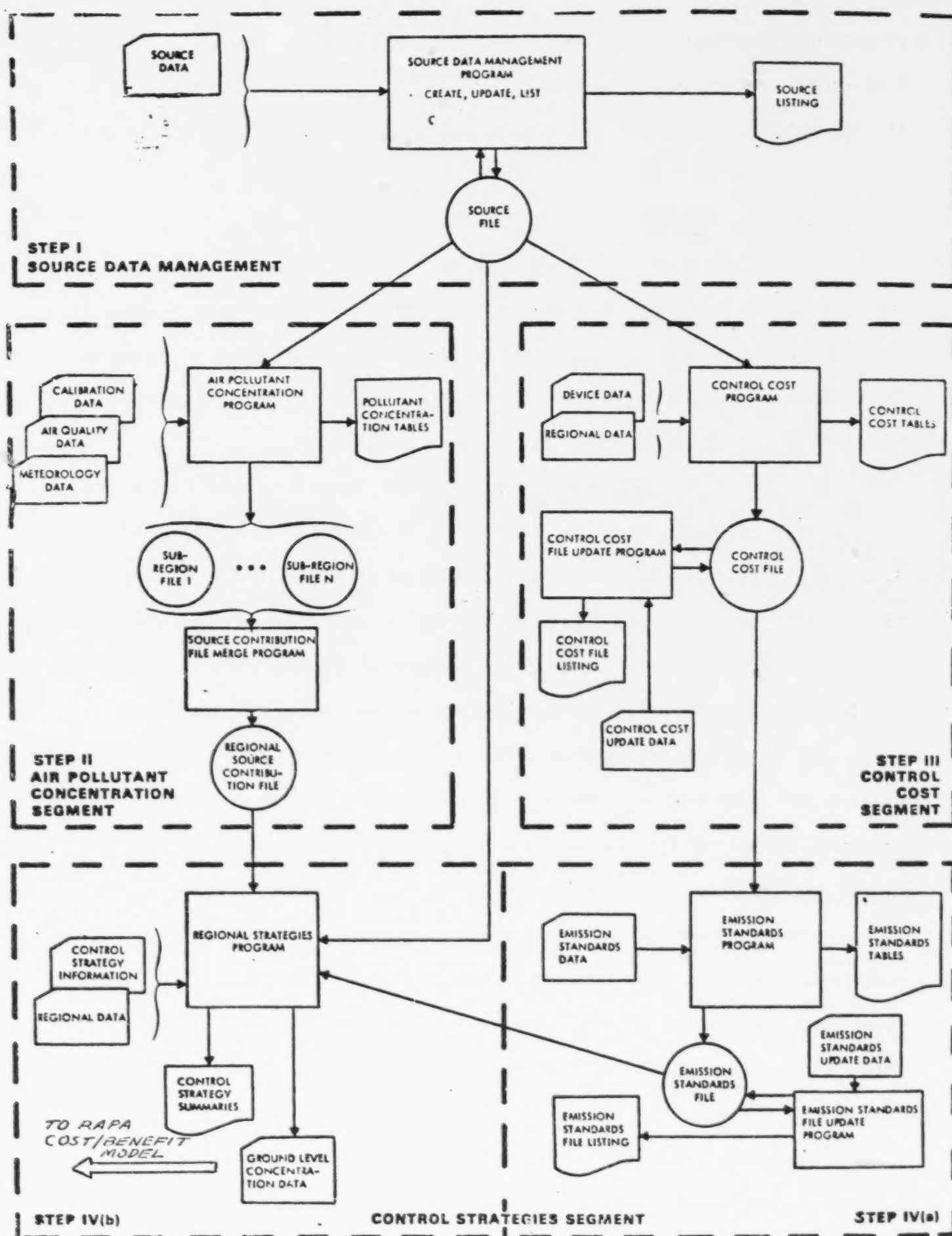


Figure 2.2-1. Structure of the Implementation Planning Program.

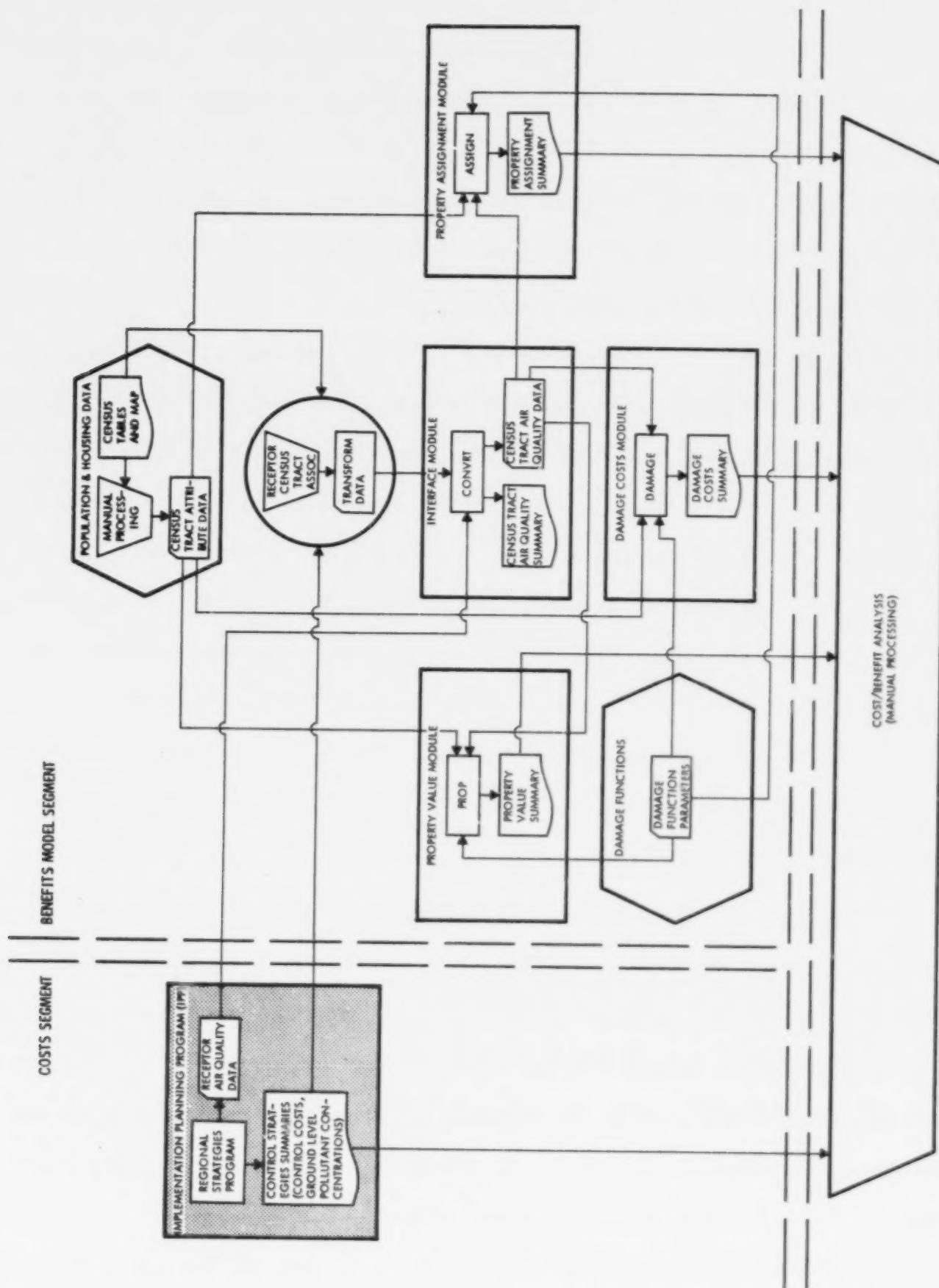


Figure 2.2-2. Role of Implementation Planning Program RAPA Cost/Benefit Model.

Program. The point source emission inventory data elements which must be supplied to the Source Data Management Program include source identification, location, source type, emission quantities, stack information, existing controls, operating schedules, fuel usage and characteristics, and process rate. The area source emission inventory data elements include location, identification, emission quantities, effective release height, and area.

(2) Air Pollutant Concentration Segment

The major program in this segment, the Air Pollutant Concentration Program, is designed to estimate the spatial distribution of sulfur dioxide and particulate matter concentrations throughout the region. The pollutant concentration output from this program is derived from (1) an atmospheric diffusion model [Martin and Tikvart, 1968], which transforms the regional source emissions and meteorological data for a given annual (or other long-term) period into estimated ground-level arithmetic average pollutant concentration values, and (2) a statistical model [Larsen, 1969] which transforms the annual arithmetic mean concentration data (at a limited number of stations) into expected maximum and short-term concentration values for specified averaging times.

Validation of the program is accomplished through use of internally calculated least-squares regression lines. These lines relate the estimated arithmetic mean concentration values produced by the program to input measured arithmetic mean pollutant concentration values. This calibration procedure makes adjustments for errors introduced by approximations in the diffusion equations, deficiencies in the meteorological and emission input data, and the neglect of topographical influences in the model.

Program output consists of data tables and a punched card deck for the arithmetic mean pollutant concentration values and, if requested, data tables

for the short-term pollutant concentration values. The punched card deck is designed for use with an x-y plotter which produces contour-line maps (isopleths) of the various concentrations levels in the region. In addition to this output, the contribution from each source to each pollutant receptor defined within the region is output on magnetic tape (defined as the Source Contribution File) for use by the Regional Strategies Program.

The meteorological data elements required by the Air Pollutant Concentration Program include stability wind rose data (wind direction, wind speed, stability class), mixing height, ambient temperature and ambient pressure. The required air quality data elements include the locations of sampling stations, background pollutant concentration values and the standard geometric deviation (24-hour average) at each station.

The other program contained in the Air Pollutant Concentration Segment is the Source Contribution File Merge Program. If more than one run of the Air Pollutant Concentration Program is required to provide the desired receptor density, the Source Contribution File Merge Program must be used to combine the several output files into a single file, as required by the Regional Strategies Program.

(3) The Control Cost Segment

In general, each point source will have several control-measure options for reducing its pollutant emission to meet each applied emission standard. The purposes of the Control Cost Program are to simulate the application of the alternative control devices available to each point source and to determine estimates of the total annual cost and efficiency of pollutant removal for each such application. The output consists of tables of control application data for each of the point sources defined in the Source File. The

data generated by the program are output in printed tabular form and on magnetic tape (defined as the Control Cost File) for use by the Emission Standards Program.

Figure 2.2-3 illustrates the results from a typical application of three control devices to a specific point source (e.g., an asphalt batching plant of a particular size). The total annual costs shown include the manufacturer's price, installation costs, annual capital charge, and the operation and maintenance costs. In computing these major expense items, the program takes into account factors such as equipment depreciation schedules, interest rates on capital, and cost or credit for pollutant disposal. The details of the cost calculations are covered in Appendix A.

The Control Cost Program requires regional data and control device information including device identification, device efficiency and rated life, device labor requirements, device costs (i.e., price, installation and operating), device applicability criteria, labor costs, alternate fuel costs, utilities costs and interest rate. A list of the control devices that are considered in the Control Cost Program is provided in Appendix A. The program provides the option of using internally preset values for certain parameters (see Appendix A).

The Control Cost Update Program, the other program in the Control Cost Segment, permits the user to input corrected or additional data into the device-source records on the existing Control Cost File and to list the contents of the file.

(4) Control Strategies Segment

The function of the Control Strategies Segment is to apply a specified control strategy so that the least costly control technology that satisfies

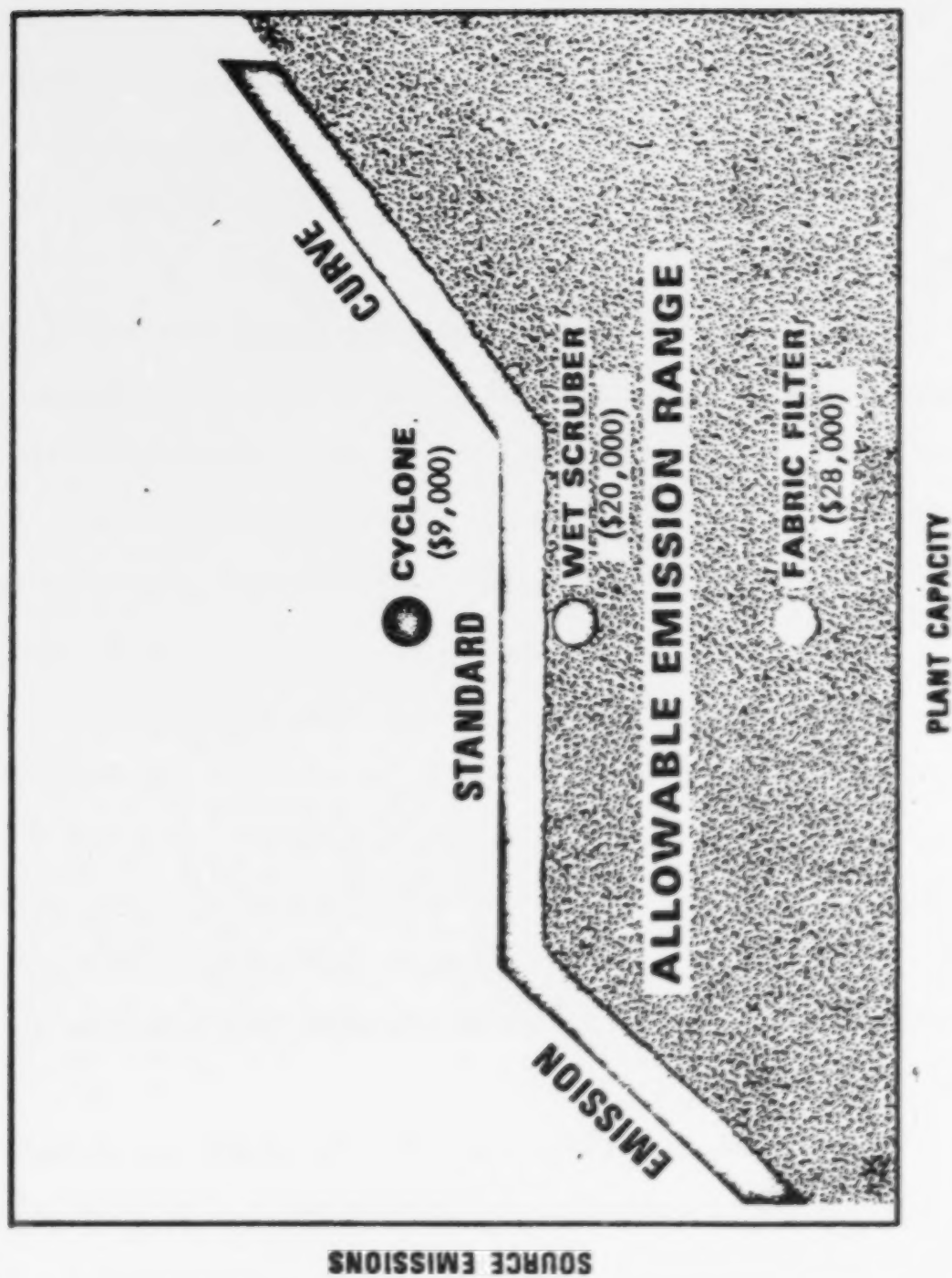


Figure 2.2-3. Typical Emission Standard Curve Relation to Control Device Application

the appropriate emission standard is applied to each source. An emission standard is a limitation placed on individual (point) sources of a particular pollutant. An implementation plan usually specifies different emission standards that are to be applied to different types of sources of each pollutant. These emission standards may be expressed in terms of mass of pollutant per unit gas volume or per unit time and will usually vary according to the size of the source. A typical emission standard used in IPP (EST19) is shown in Figure 2.2-4.

On the other hand, an emission control strategy consists of selected emission standards covering all significant (point) source types. For particulate emissions, the significant source types considered by IPP include fuel combustion, industrial processes and solid waste disposal. For sulfur oxides, only fuel combustion and industrial processes are considered.

The Control Strategies Segment provides sufficient output information to evaluate the regional impact of selected strategies from the standpoints of; (1) the types of sources affected by the strategy; (2) the degree to which these sources are affected in terms of control costs; (3) the resulting changes in pollutant emissions; and (4) the regionally aggregated values of control costs by source category, total reduction in pollutant emissions, changes in regional fuel-use patterns, and resulting air quality levels.

The Control Strategies Segment performs the simulation process through use of the Emission Standards Program and the Regional Strategies Program. The analyst first selects all candidate emission standards (e.g., Figure 2.2-4) for consideration by the Emission Standards Program. The program then compares the requirements of each standard with the data generated by

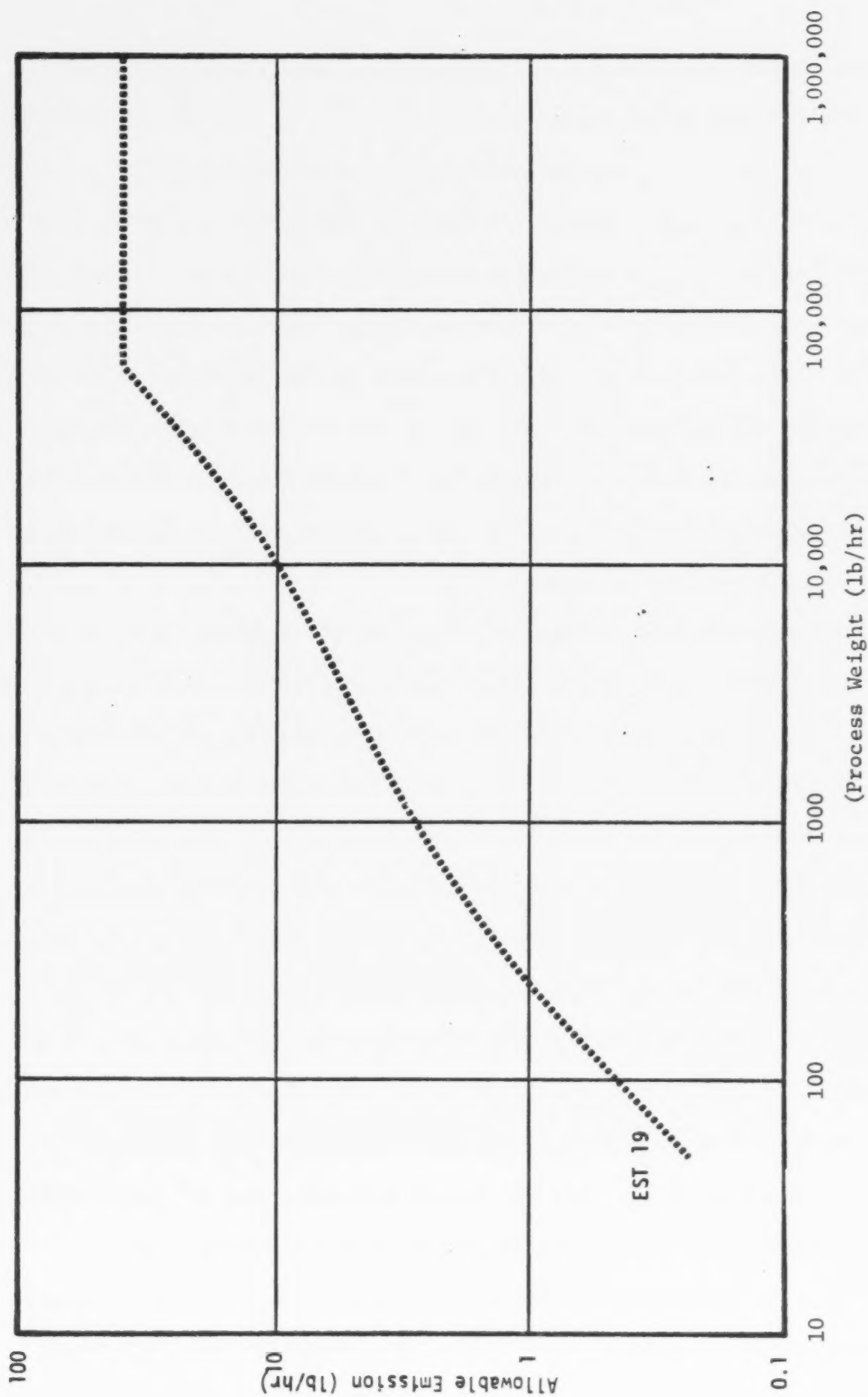


Figure 2.2-4. Allowable Particulate Emissions Based on Industrial Process Weight (EST 19).

the Control Cost Program. The program selects the most cost-effective device for each point source under each standard. In the example shown in Figure 2.2-3, the program would select the wet scrubber.

The data generated by the Emission Standards Program are output in the form of printed tables for user review and on magnetic tape (defined as Emission Standards File) for use by the Regional Strategies Program. The table output illustrates the actual control measures selected for each source, the annual costs, and data on the degree to which emissions have been controlled. If necessary, the Emission Standards File may be updated by the Emission Standards File Update Program, the third program in the Control Strategies Segment.

Finally, the analyst selects a set of standards to be applied (i.e., an emission control strategy) by the Regional Strategies Program. The program summarizes the existing, allowable and controlled emissions for the sources and generates new air quality data based on allowable or existing emission rates (whichever is less). Reduction of each area source emission rate is accomplished by user input scale factors. The Regional Strategies Program requires inputs from the Emission Standards File, the Source File (area source data), and the Source Contribution File.

Output from the Regional Strategies Program consists of regional and political jurisdictional summaries of regional costs, regional emissions, number of sources affected by a given standard, and figures of merit for each strategy (e.g., cost per ton of pollutant removed, cost per microgram or per cubic meter of reduced ground-level concentrations).

The ground level concentration data for the controlled conditions are also output in punched card form. This deck becomes direct input for the RAPA Cost/Benefit Model. In addition, the tabular output provides essential

data for the Costs Segment of the Cost/Benefit analysis. Due to the importance of the output of the Control Strategies Program to the Cost/Benefit Model, further details are provided in Section 2.2.2.

2.2.2 Point Source Cost Calculations in IPP

The only cost data employed in the RAPA Cost/Benefit Model at the present time are generated entirely within the Control Cost Program and Regional Strategies Program of IPP. The IPP model currently only estimates the direct costs of emission control to the major point sources. These point sources cover both the public and private sectors of the regional economy, however, and their control costs generally form a significant portion of the total control cost to the region. These costs are generally acceptable for cross-sectional cost/benefit analysis.

Possible procedures for estimating control agency and area source control costs have been given by K. Woodcock [1971]. These procedures form a potential basis for extending the present RAPA Cost/Benefit Model in the future.

Appendix A provides the details of the point source control cost calculations as performed in IPP.

2.2.3 IPP Regional Strategies Output

The Regional Strategies Program output from IPP provides direct punched card input for the RAPA Cost/Benefit Model and tabulated data required in the cost/benefit analysis.

2.2.3.1 Tabulated Output for Cost/Benefit Analysis

The Regional Strategies Program provides four types of tabulated data useful in cost/benefit analysis. These are as follows:

Emission Standard Effects on Source Emissions

The tabulation shown in Figure 2.2-5 is presented for each source type/political jurisdiction combination. A header indicating the regional identification, control strategy number and descriptive name, and date precedes each table. The source type, emission standard number and jurisdiction also are printed before the main tabular listing. The following items make up the column headings in this tabulation:

- Source Identification. Each source is identified by its SIC code, site and process numbers.
- Control Device. The device selected by the Emission Standards Program for this standard is identified by its numeric code (see Appendix A). The computed annual cost and device efficiency are also shown.
- Required Efficiency. This decimal efficiency represents the degree of pollutant reduction required by the source to bring its potential emissions into compliance with the allowable emission defined by the control standard. If the source already has an existing control device then the required efficiency will be larger than that needed to bring the existing (partially controlled) emissions into compliance with the standard.
- Emissions. Three emission rates are displayed for each source: the existing emissions, the emissions allowable under the emission control standard, and the controlled emissions resulting from the application of the listed control device. The allowable emissions are utilized in the computation of air quality resulting from the application of the control strategy.

Jurisdictional Summary

Following the presentation of the Emission Standard Effects on Source Emissions for each of the three source types within a political jurisdiction, a jurisdictional summary is printed (Figure 2.2-6). Again, a table header

EMISSION STANDARD EFFECTS ON
SOURCE EMISSIONS

SIC CODE	SITE NO.	PROC. VOLT.	DEVICE ID	ANNUAL DEVICE COST	DEVICE EFFICIENCY	REQUIR'D EFFICIENCY	EMISSIONS (TONS/YR)	
							EXISTING	ALLOWABLE
2119	1	25	00 C	\$ C.C	C.C	0.0	0.10	0.10
2819	34	2	00 C	\$ 0.0	C.C	C.0	C.21	C.21
2819	160	3	14	\$ 52496.33	0.99000	0.96712	21.90	0.22
2951	150	1	1	\$ 7846.25	0.98000	0.92503	0.97	0.07
3241	100	1	10	\$ 235426.44	0.94600	0.99000	2.79	0.15
3295	51	1	18	\$ 41600.02	0.94000	0.98749	19.18	0.19
3332	270	1	0	\$ C.C	C.0	0.97677	0.31	0.31
3332	270	1	0	\$ C.C	C.0	0.97677	0.31	0.31

(*) INDICATES MOST EFFICIENT DEVICE WAS USED BUT ALLOWABLE WAS NOT ATTAINED.
 (00) INDICATES NO DEVICE AVAILABLE TO CONTROL THE SOURCE
 (G) INDICATES GAS COOLING WAS REQUIRED PRIOR TO DEVICE APPLICATION.

CENTRAL CITY STRATEGY II PARTICULATE M.I./P.E.

NOVEMBER 18, 1970

JURISDICTION SUMMARY

STATE A JURISDICTION

REGULATION TYPE AND NUMBER	TOTAL APPLICABLE POINT SOURCES	TOTAL CONTROLLED POINT SOURCES	EXISTING EMISSIONS FOR POINT SOURCES (TNS/DAY)	EMISSION REDUCTION (TNS/DAY)	ANNUAL CONTROL COST (MILLIONS OF \$)	CONTROL COST PER TON REMOVED (\$/TON)
FUEL COMBUSTION 8	2	2	5.70	C.C.C 5.68	0.386	4045.63
INDUSTRIAL PROCESS 5	8	4	45.48	3.67	0.338	20.89
SOLID WASTE DISPOSAL 5	2	1	2.88	0.29	0.129	141.59
JURISDICTION TOTAL	12	7	54.06	3.96	0.853	462.53

(*) SOME SOURCES COULD NOT ATTAIN THE ALLOWABLE EMISSION
(**) NO DEVICE AVAILABLE TO CONTROL SOME SOURCES.
(G) GAS CLOSING APPLIED TO SOME SOURCES.

JURISDICTION EMISSIONS JURISDICTION EMISSIONS

EXISTING EMISSIONS (TNS/DAY)	CONTROLLED EMISSIONS (TNS/DAY)	
POINT SOURCES.... 54.1	POINT SOURCES.... 1.6	COAL (TNS/DAY)..... 0.0
AREA SOURCES..... 16.1	AREA SOURCES..... 14.8	RESID. JIL (GAL/DAY)..... 0.0
TOTAL EMISSIONS.. 70.1	TOTAL EMISSIONS.. 16.4	DIST. JIL (GAL/DAY)..... 0.0
CONTROLLED REDUCTION.. 53.7	PERCENTAGE REDUCTION... 76.6	GAS (1000 CU. FT./DAY)... 91216336.000

JURISDICTION CONTROL COST - EFFECTIVENESS

REDUCTION IN TOTAL POINT SOURCE EMISSION RATE 462.53 DOLLARS/TON

Figure 2.2-6. Output Format - Jurisdiction Summary

is provided which identifies the control region and the emission control strategy under consideration. The run date and political jurisdiction are also displayed. The following data elements are included in the tabular presentation:

- Regulation Type and Number. The emission standard applied to each source type is identified by number.
- Total Applicable Point Sources. The number of point sources is listed both by source category and as a total for the jurisdiction.
- Total Controlled Point Sources. The number of sources required to reduce their pollutant emissions are tabulated in this column. Indicators are provided when certain of the sources cannot be properly controlled by the devices considered in the Control Cost Program.
- Existing Emissions for Point Sources. This column summarizes the existing pollutant emissions by source category.
- Emission Reduction. Two measures of emission reduction are included under this heading. Allowed emissions refer to the emission levels specified by the emission standards making up the control strategy. Controlled emissions indicate the amount of reduction produced by the control devices selected by the program to bring each source into compliance with the allowable emission levels. It must be noted that the two sets of figures in this column are not strictly comparable since the control device selected may produce a greater reduction than is required by the standard. Also, in some cases, there may be no control device available which allows a source to meet the emission level specified by the standard.
- Annual Control Cost. This column presents the accumulated control costs of the control devices assigned to each point source under the control strategy.
- Control Cost per Ton Removed. The figures presented in this column represent the product of the annual control cost divided by the number of tons of pollutant removed annually by the control device. These figures give an estimate of the cost effectiveness of control by source categories and overall effectiveness.

In addition to the main tabulation, described above, the Jurisdictional Summary also contains a summary of the emission pattern prior to and following the application of the control strategy. Both point and area source

emissions are included in this summary. The reduction in area source emissions shown indicates the effect of the area source scale factors input by the user. The jurisdictional fuel use patterns following application of the control strategy are also displayed.

Control Strategy Summary

Figure 2.2-7 provides an overall summary of the pollutant reductions required under the control strategy. The header information and column headings are the same as for the jurisdictional summaries described above. This tabulation represents the summation of control information over the entire air quality control region. One additional piece of information is included in this output which was not in the previous summaries. The reduction in ground level concentration indicates the number of dollars required to produce an average one microgram/cubic meter reduction in the regional pollutant levels. This value will vary between control strategies and thus provides another measure of effectiveness of each strategy.

Control Strategy Effects on Ground Level Concentrations

The result of the pollutant emission reductions on ambient air quality throughout the region is displayed in Figure 2.2-8. The table header identifies the control region, control standard and the run date. The air quality standard for the pollutant being controlled is also shown. Each receptor location is identified with a unique number and by its X and Y coordinates. The expected pollutant concentration following the application of the control strategy is indicated in micrograms/cubic meter. The amount of reduction from the existing ambient conditions is also displayed in a separate column. The amount by which the concentration at each receptor point is in excess of the ambient air quality standard is also shown.

2.2.3.2 Punched Card Output for Cost/Benefit Model

The control strategies effects on ground level concentrations provided in printed tabular form (Figure 2.2-7) was described above. This data is also produced in punched card form so that an isopleth plot can be produced for easy visualization of the resulting pollutant concentrations.

CENTRAL CITY STRATEGY II PARTICULATE M.I./P.E.

NOVEMBER 18, 1970

CONTROL STRATEGY SUMMARY

JURISDICTION AND NUMBER	TOTAL APPLICABLE POINT SOURCES	TOTAL CONTROLLED POINT SOURCES	EXISTING EMISSIONS FOR POINT SOURCES (TONS/DAY)	EMISSION REDUCTION (TONS/DAY)	ANNUAL CONTROL COST (MILLIONS OF \$)	CONTROL COST PER TON REMOVED (\$/TON)
STATE A	12	7	54.06	3.96	8.853	462.53
STATE B	14	8	28.20	6.16	16.364	1767.31
STRATEGY TOTAL	26	15	82.26	10.12	25.217	887.95

(*) SOME SOURCES COULD NOT ATTAIN THE ALLOWABLE EMISSION
 (**) NO DEVICE AVAILABLE TO CONTROL SOME SOURCES.
 (G) GAS COOLING APPLIED TO SOME SOURCES.

REGIONAL EMISSIONS

REGIONAL EMISSIONS

EXISTING EMISSIONS (TONS/DAY)	CONTROLLED EMISSIONS (TONS/DAY)	
POINT SOURCES.... 82.3	POINT SOURCES.... 4.5	COAL (TONS/DAY)..... C.C
AREA SOURCES..... 20.1	AREA SOURCES..... 18.4	RESID. OIL (GAL/DAY)..... C.C
		DIST. OIL (GAL/DAY)..... C.C
TOTAL EMISSIONS.. 102.3	TOTAL EMISSIONS.. 22.8	GAS (1000 CU. FT./DAY)....276613120.CC
CONTROLLED REDUCTION.. 79.5	PERCENTAGE REDUCTION... 77.7 %	

REGIONAL CONTROL COST - EFFECTIVENESS

REDUCTION IN TOTAL POINT SOURCE EMISSION RATE 887.95 DOLLARS/TON
 REDUCTION IN GROUND LEVEL CONCENTRATION . . . 25081840. COLLARS/MICROGRAM/CUBIC METR

Figure 2.2-7. Output Format - Control Strategy Summary

CENTRAL CITY STRATEGY II PARTICULATE M.I./P.E.

NOVEMBER 18, 1970

CONTROL STRATEGY EFFECTS ON GROUND LEVEL CONCENTRATIONS

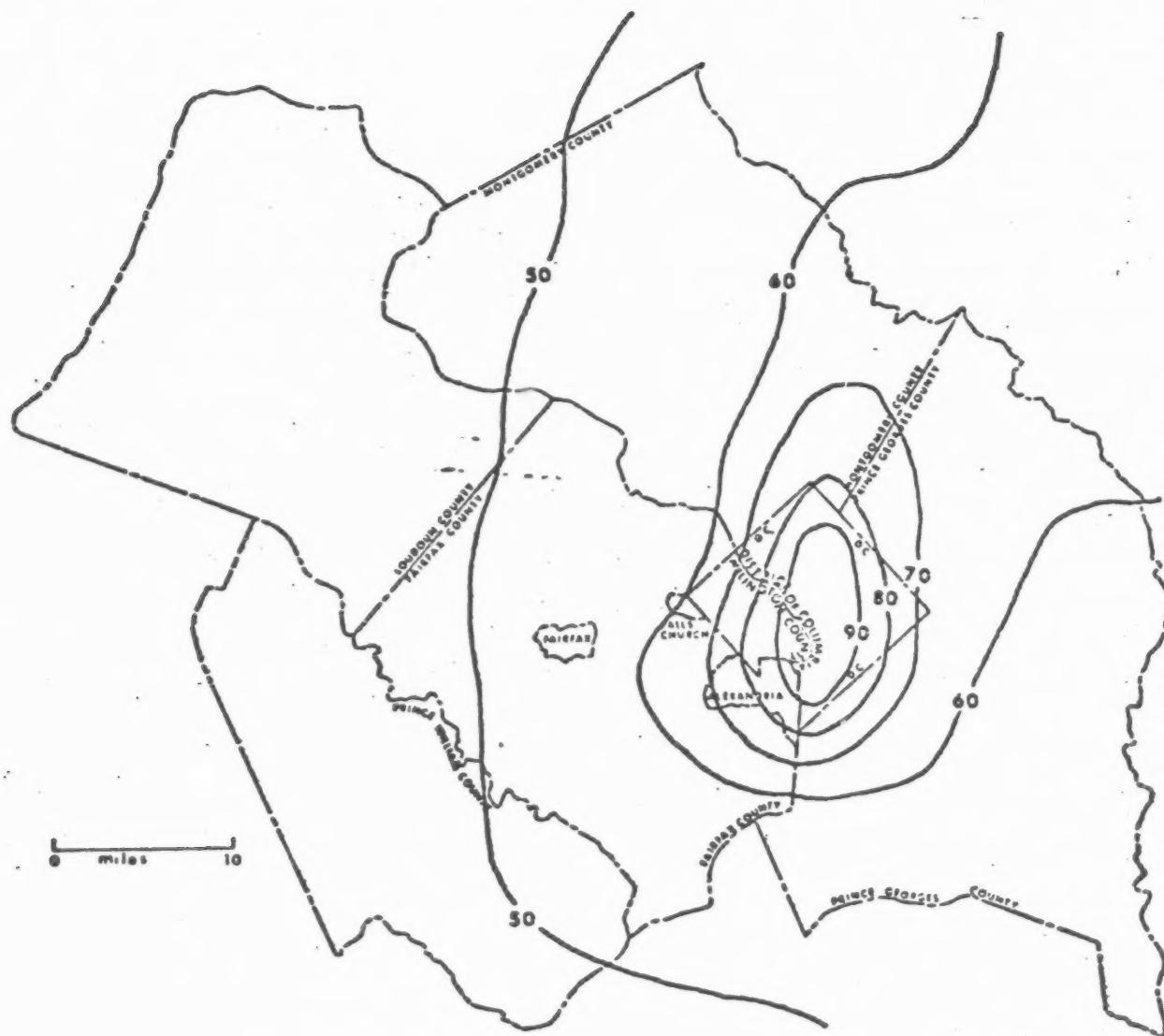
AIR QUALITY STANDARD 65-0		MICROGRAMS/CUBIC METER		C.O Y= 0-0	
UTM ORIGIN (KILOMETERS): X=		Y=		C.O Y= 0-0	
RECEPTOR	LOCATIONS	UTM, KILOMETERS	NEW CONCENTRATION VALUE	AMOUNT REDUCED	AMOUNT IN EXCESS
NUMBER					
1		60.00	0.72846E 01	0.508694E 00	0.0
2		60.00	0.570159E 01	0.508694E 00	0.0
3		65.00	0.846338E 01	0.508694E 00	0.0
4		65.00	0.627230E 01	0.508694E 00	0.0
5		65.00	0.841251E 01	0.508694E 00	0.0
6		90.30	0.202217E 02	0.508694E 00	0.0
7		60.00	0.695873E 01	0.508694E 00	0.0
8		90.00	0.191558E 02	0.508694E 00	0.0

Figure 2.2-8. Output Format - Ground Level Concentrations

Figure 2.2-9 illustrates the existing ground-level particulate concentrations in the NCIAQCR as predicted by the calibrated Air Pollutant Concentration Program. In this region, the goal of the implementation plan was to attain an annual arithmetic average of particulate concentrations of $86.6 \mu\text{g}/\text{m}^3$ as an interim standard and $65.2 \mu\text{g}/\text{m}^3$ as a long-term standard. In testing the acceptability of a strategy, the IPP model is used to ascertain that the annual average concentration does not exceed the long-term air quality standard at any point in the AQCR.

To meet the above standards, a control strategy for reduction of the particulate concentration was required. The isopleths in Figure 2.2-9 indicate that annual average concentrations above $90 \mu\text{g}/\text{m}^3$ were observed in the NCIAQCR. Concentrations of up to $107.7 \mu\text{g}/\text{m}^3$ could be expected within this $90 \mu\text{g}/\text{m}^3$ isopleth (the $100 \mu\text{g}/\text{m}^3$ isopleth was too small to be drawn on the map). Analytical results for 19 control strategies are presented in Table 2.2-1. The reduction in emissions from point and area sources is indicated, as well as the control cost expected and the pollutant concentrations at the maximum receptor in the region. Strategy 18 was selected for the District of Columbia, on the basis of (1) control costs, (2) expected air quality (which, within experimental error, approximated the air quality standard), and (3) the assumption that the emission control technologies required to meet the strategy were technically feasible and economically reasonable. Particulate levels expected after the application of the proposed control strategy are illustrated in Figure 2.2-10.

In addition to providing isopleths of air pollutant concentration levels over the region, the punched card output provides direct input to the RAPA Cost/Benefit Model (CONVRT). The data which is initially on a receptor basis must be converted to census tract mean concentrations. The method used to accomplish this and the computer program module which automatically performs the transformation are discussed in Section 2.6.



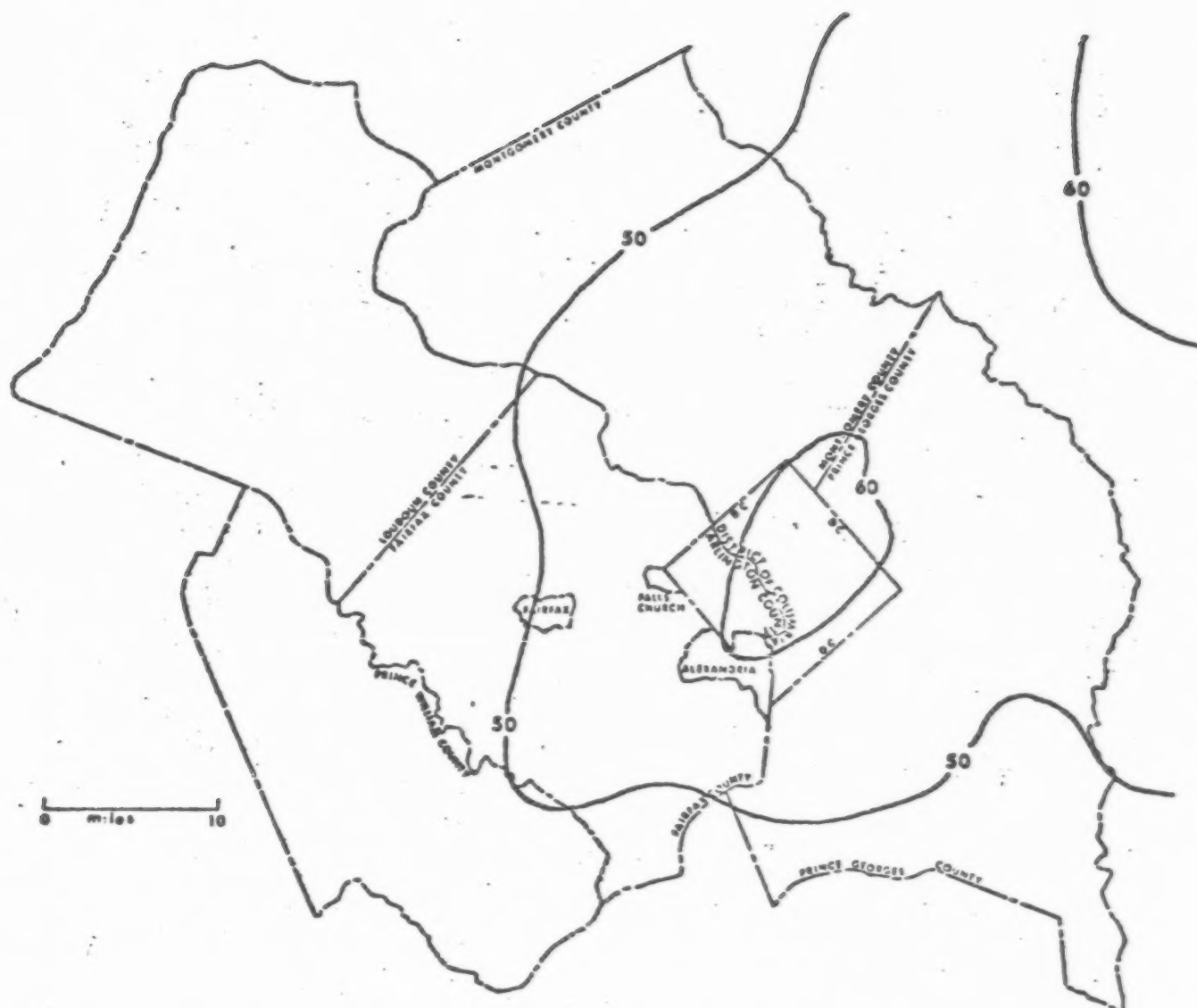
NOTE: Annual Concentration in $\mu\text{g}/\text{m}^3$

Figure 2.2-9. Existing Ground Level Particulate Concentrations in the NCIAQCR as Computed by the Verified Air Pollutant Concentration Program.

Table 2.2-1. Particulate Control Strategies - National Capital Interstate Air Quality Control Region.

Strategy Number	POINT SOURCES		AREA SOURCES		CONTROL COST		Maximum Receptor (µg/m ³)
	Percent Reduction	New Emission Rate (tons/day)	Percent Reduction	New Emission Rate (tons/day)	\$ x 10 ⁶	\$/ton removed	
Existing**	--	(84.7)	--	(75.6)	--	--	--
1	36.3	54.0	18.0	62.0	0.5	47	107.7
2	87.4	10.7	51.4	36.7	13.9	514	92.2
3	62.2	32.0	47.5	39.7	4.0	210	90.0
4	52.7	40.1	48.6	38.9	4.4	267	76.0
5	86.4	11.6	51.4	36.7	11.8	471	69.4
6	78.2	18.4	51.4	36.7	11.6	489	69.7
7	76.0	19.9	51.4	36.7	11.6	489	69.7
8	36.3	54.0	36.3	48.2	0.5	47	89.8
9	41.0	50.0	18.6	61.6	0.6	44	81.8
10	77.0	19.5	51.4	36.7	11.6	489	70.0
18	70.4	25.0	51.4	36.7	10.8	498	68.2

** Existing conditions based on the 1969 inventory collected for the NCAQCR and the validated diffusion model.



Note: Annual Concentrations in $\mu\text{g}/\text{m}^3$

Figure 2.2-10. Predicted Particulate Concentrations After the Enactment of the Proposed Emission Control Strategy in all Political Jurisdictions.

2.3 CENSUS TRACT DATA

A central task of the RAPA Cost/Benefit Model is to provide a measure of the effects of air pollution on people and property. In order to perform this task, the model must be supplied data on regional air quality, population and property distributions (Figure 2.3-1, shaded portions). The air quality data is generated by IPP, previously described in Section 2.2. The population and property data on the other hand, are available from the Bureau of the Census. The census tract data was selected because the decennial censuses of population and housing provide the required detailed information on the population of a region and the individual and household characteristics. These data are supplied on a census tract basis.

The Department of Commerce defines census tracts as follows:

"Census tracts are small, permanently established, geographical areas into which large cities and their environs have been divided for statistical purposes. Tract boundaries are selected by local committee and approved by the Bureau of the Census. They remain the same for a long time so that statistical comparisons can be made from year to year and from census to census. The average tract has over 4,000 people and is originally laid out with attention to achieving some uniformity of population characteristics, economic status, and living conditions. In each decennial census, the Bureau of the Census tabulates population and housing information for each tract--hence, the name "census tract".*

The criteria* employed in defining census tracts are as follows:

- Population Size - A census tract should contain between 2500 and 8000 inhabitants, but may contain somewhat more. Tracts covering a large population are desirable if the population is homogeneous. The average size for all tracts should not be less than 4000 inhabitants.

*These descriptions have been condensed from the Census Tract Manual.

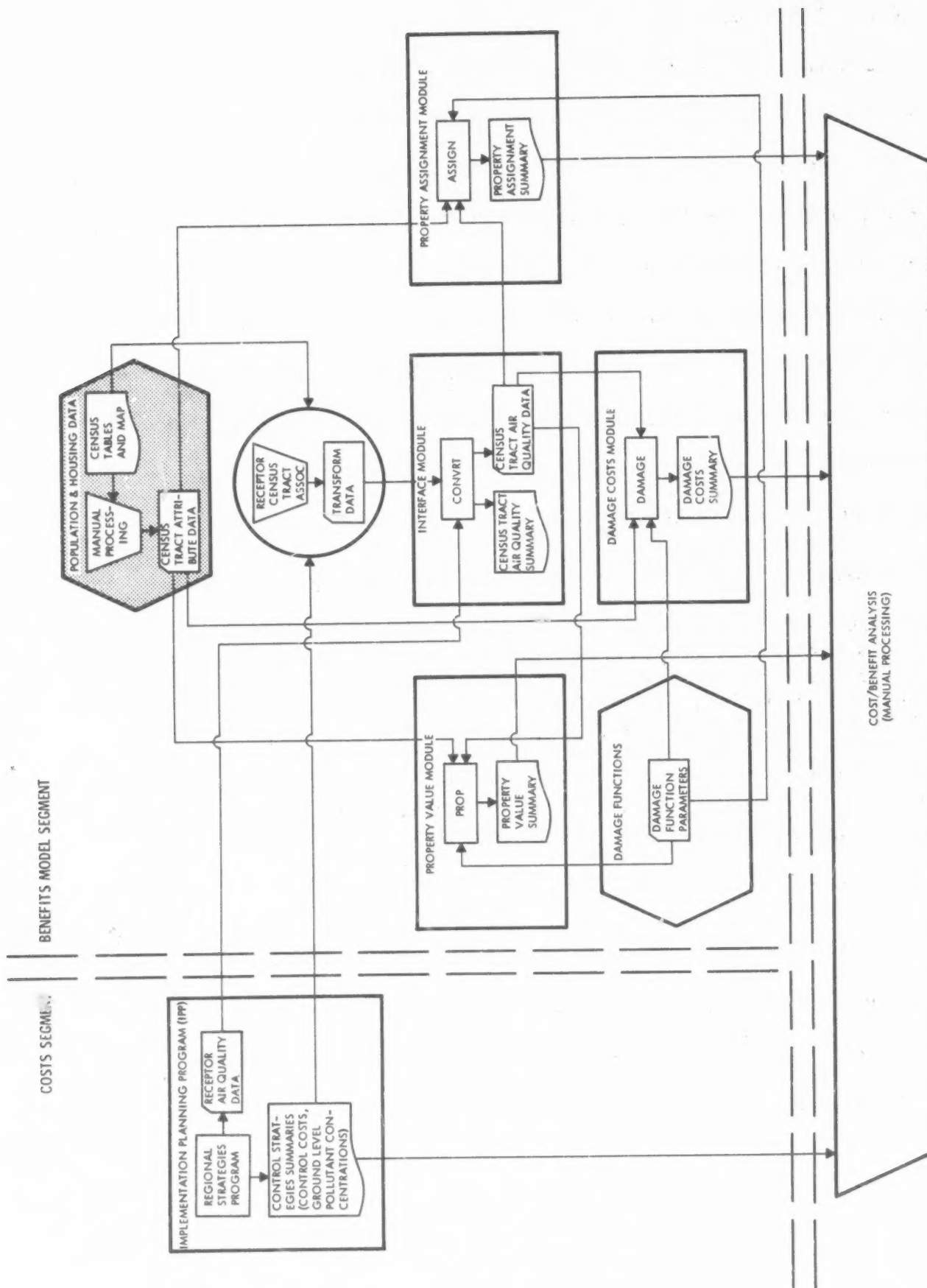


Figure 2.3-1. Population and Housing Data Relation to RAPA Cost/Benefit Model.

- Boundaries - Census tract boundaries should follow permanent and easily recognized lines (state lines, highways, railroads, rivers, streams, channels, and the like). Alleys are normally not used and should not be unless named.
- Homogeneity - Census tracts should contain, insofar as it practicable, persons of similar racial or nationality characteristics, of similar economic status, and of similar housing. If a tract includes both expensive homes and slum dwellings, for example, average statistics for the tract as a whole will not reflect the condition of either group.
- Geographic Shape and Size - In general, a census tract should be compact. It is desirable to avoid panhandles, L's, dumbbells, and other elongated shapes. Irregular boundaries should be avoided wherever possible.

The cost/benefit analysis example for this report involves the Washington, D. C. Standard Metropolitan Statistical Area (SMSA). An SMSA (except in New England) has the following properties:

- (1) It contains either one county or a group of contiguous counties.
- (2) The county group must contain either one central city of at least 50,000 inhabitants or "twin cities" with a total population of at least 50,000 inhabitants.
- (3) The counties included in the SMSA must either contain the central city or form a socially and economically integrated metropolitan area with the central city.

The Washington, D. C. SMSA consists of: the District of Columbia; Arlington County, Fairfax County, Alexandria City and Falls Church City in Virginia; Montgomery County and Prince Georges County in Maryland.

The census data employed here is from the 1960 census. The 1970 census information is not available in published form at the present time. Appendix B provides information on the census tract attributes themselves and the sources of census tract information.

2.4 AIR POLLUTION DAMAGE FUNCTIONS

If costs and benefits of air pollution control are to be analyzed on a quantitative basis, then they must somehow be related on a common scale. The traditional scale of convenience for cost/benefit analysis is "price." However, since there is no marketplace as such for clean air, the price must somehow relate to society's willingness to pay to reduce air pollution, (i.e., the effects). The willingness to pay for clean air can be best related to the avoidance of the damages of air pollution to the society. Thus, the benefits of improved air quality are the reduction in damages that would otherwise occur due to the presence of pollutants. The next logical requirement is to express these damages on a price scale (in dollars). The relation of the damage functions to the various modules of the RAPA Cost/Benefit Model is illustrated in Figure 2.4-1.

2.4.1 Direct Damage Functions

There have been various attempts recently to produce damage functions; most of these have been efforts to quantify one or more of the direct effects of air pollution. A simple example which illustrates the basic form is the damage function developed by Wilson and Minnotte* for the Washington, D.C., metropolitan area (Figure 2.4-2). The damage function relates per capita annual soiling cost to concentrations of suspended particulates. The authors utilized the results of air pollution statistical studies in the Washington, D. C., area conducted by Irving Michelson. Michelson's study

* R. D. Wilson and D. M. Minnotte, "A Cost-Benefit Approach to Air Pollution Control," Journal of the Air Pollution Control Association, Vol. 19, No. 5, p. 306, May 1969.

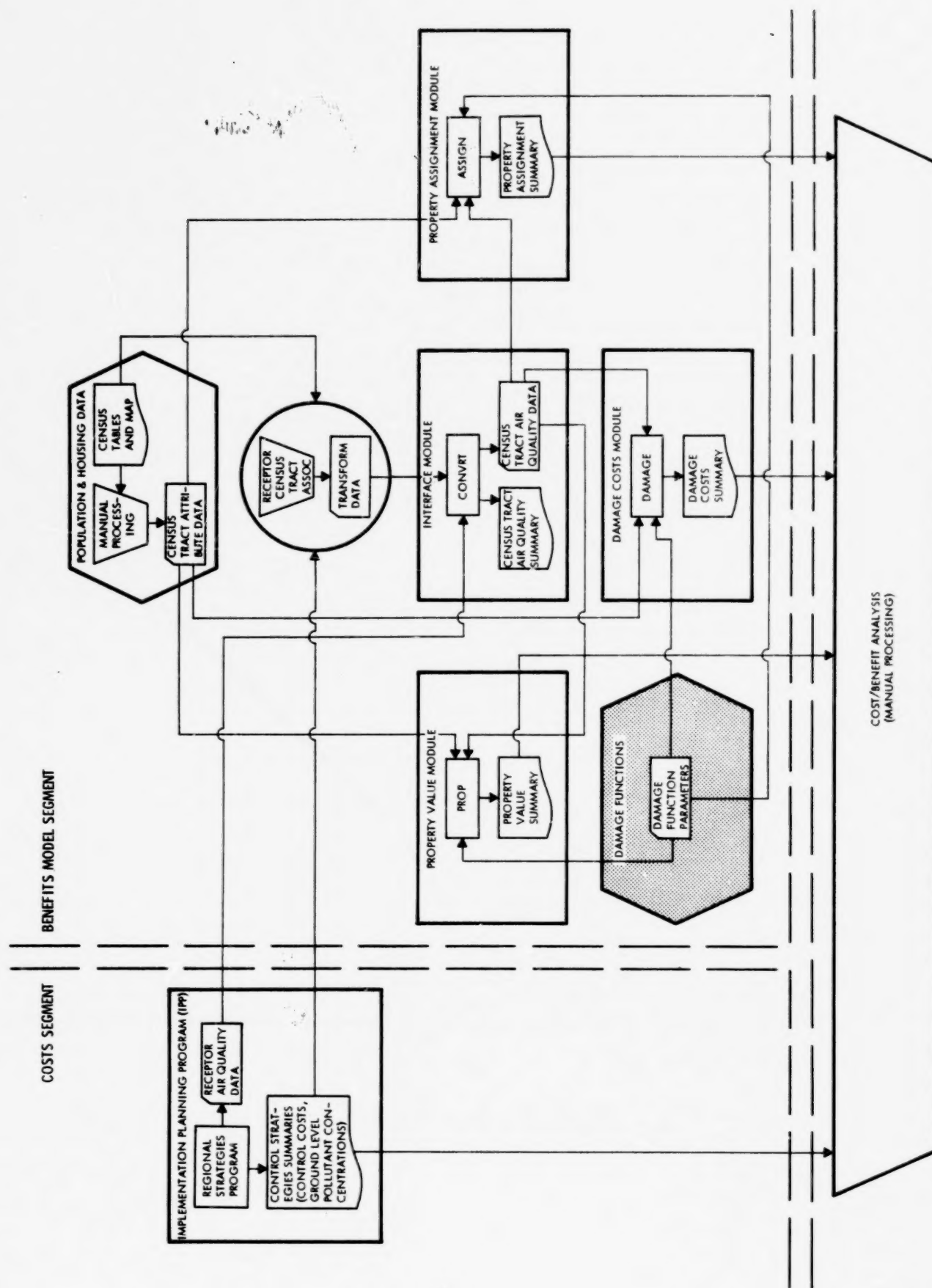


Figure 2.4-1. Damage Functions: Role in the RAPA Cost/Benefit Model.

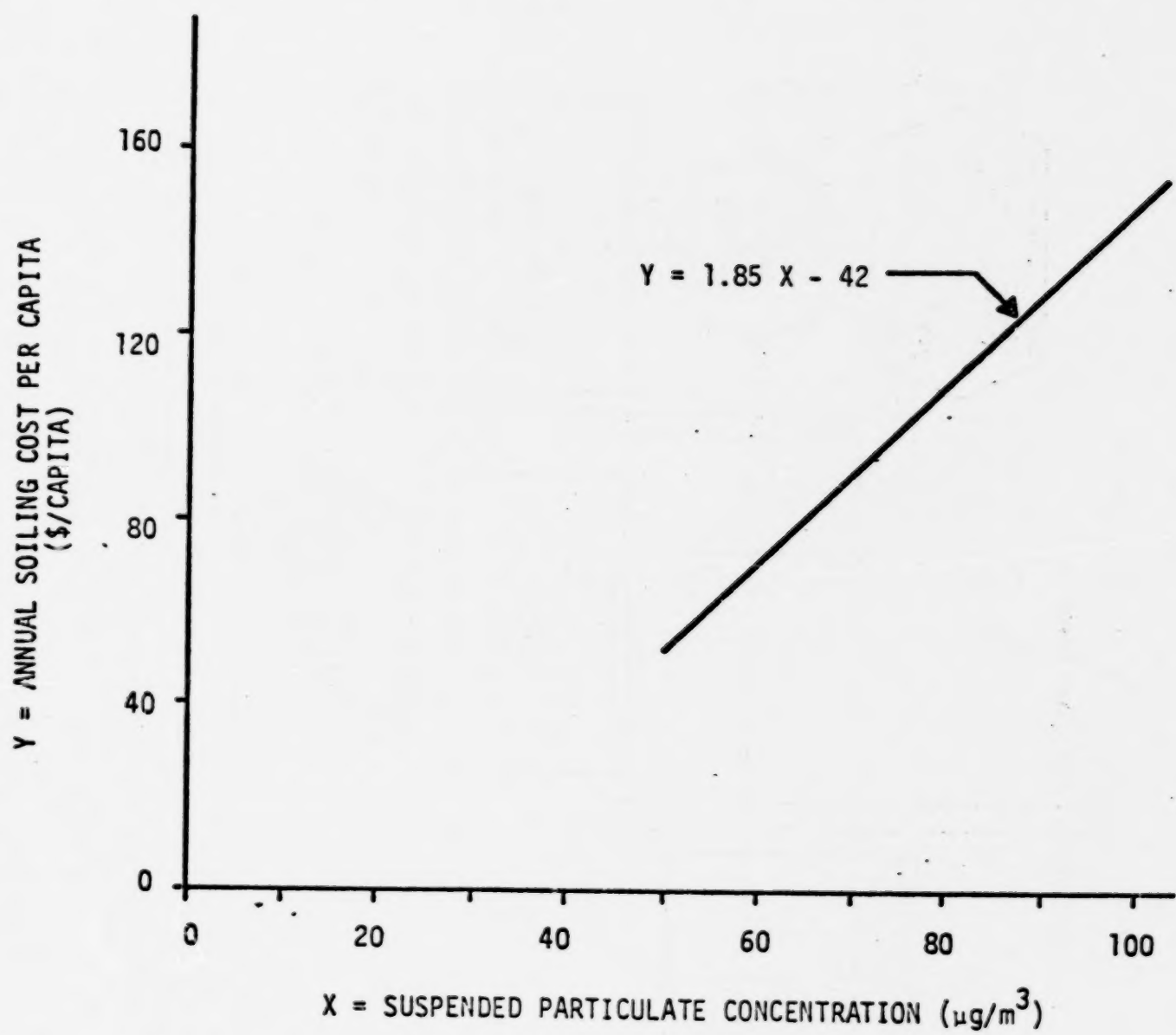
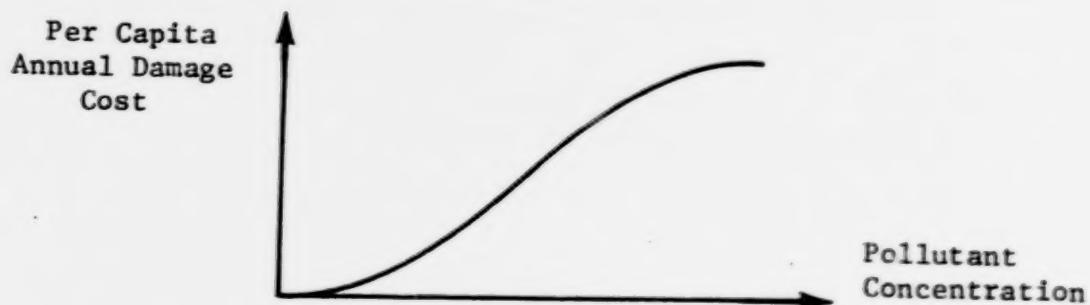


Figure 2.4-2. Wilson and Minnotte Function for Damages Due To Soiling

used responses to a questionnaire to determine the frequency of certain household cleaning chores in areas of high and low air pollution within the metropolitan area.*

This function provides a simple linear relation between the annual per capita soiling cost and the average annual particulate concentration in $\mu\text{g}/\text{m}^3$. Soiling, of course, represents a small part of the direct damages due to air pollutants. The direct damage function employed in the Cost/Benefit Model Demonstration for the NCIAQCR is also a linear function of the same form as the Wilson-Minnotte relation. However, the Pro Forma Damage Function (Figure 2.4-3) used here represents an effort to provide a gross estimate of national damages across the full range of direct effects. A detailed explanation of the development of these damage functions (note that there are two functions, one for SO_2 and one for particulates) is given in Appendix C. Before continuing on, however, we should note that linear damage functions merely represent the best that can be done at the present time. There is no reason to believe that they are universal. In fact, one would expect further research to reveal a direct damage function of the form shown below.



An initial slow rise followed by sharply increasing slope is to be expected.

* I. Michelson, "The Household Cost of Living in Polluted Air in the Washington, D. C. Metropolitan Area," A Report to the U. S. Public Health Service.

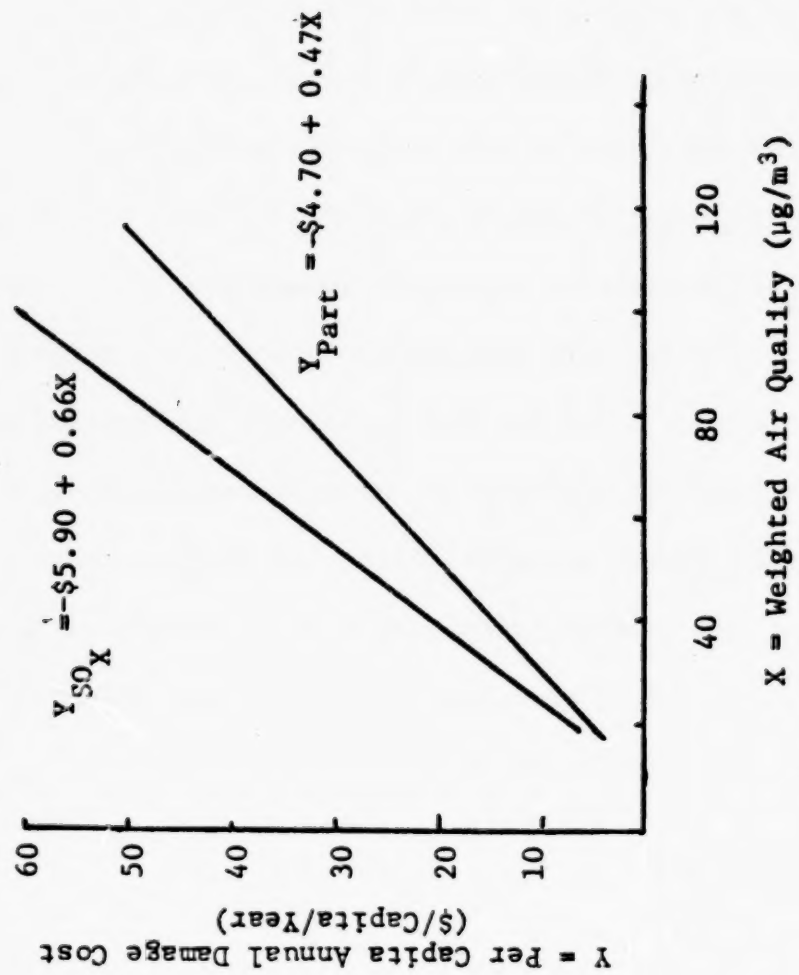
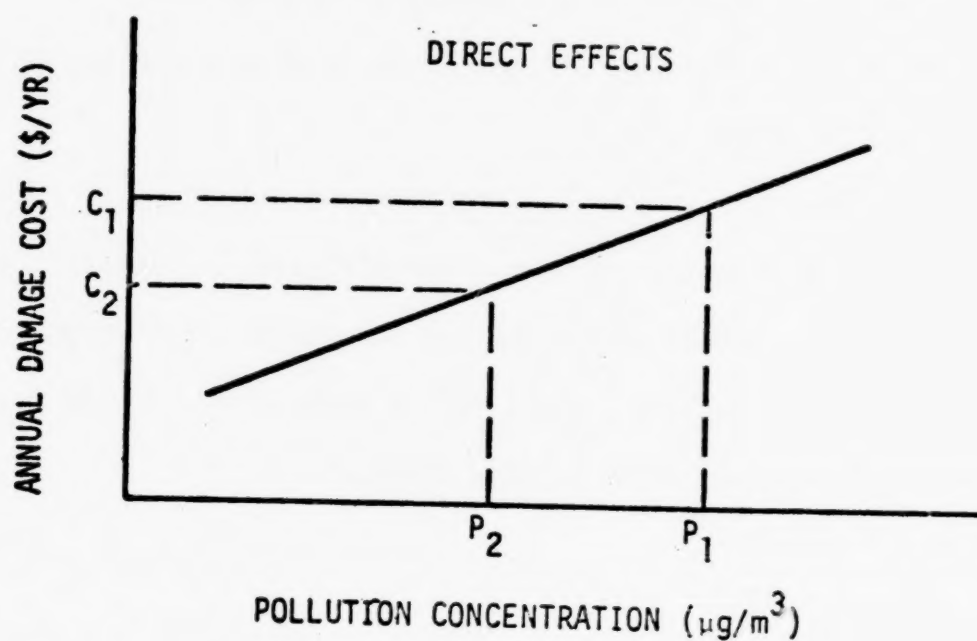


Figure 2.4-3. Pro Forma Damage Functions Used In RAPA Cost/Benefit Model NCIQCR Demonstration

This feature would result from the "threshold" effects exhibited by many forms of pollution damage. Similarly, a leveling off at high concentrations due to "saturation" effects may be anticipated.

Damage functions are generally expressed in relation to the population (or number of households) and pollution concentration. In the RAPA Cost/Benefit Model, damage functions are applied to each census tract in an AQCR (or SMSA) to determine the census tract damage cost. The sum of the damage costs for all census tracts in an AQCR determines the AQCR damage cost.

The damage estimates of the direct effects of pollution are estimated as a function of particulate and/or sulfur dioxide concentrations for the base alternative (i.e., the existing condition) as well as for predicted concentrations under a given emission control strategy. Social benefit is considered to be the difference between the damages from the base alternative and damages after application of the control strategy. This concept is demonstrated in the following figure:



$$C_1 = (\text{DAMAGE COST})P_1; C_2 = (\text{DAMAGE COST})P_2$$

$$\text{SOCIAL BENEFIT} = C_1 - C_2$$

2.4.2 Market Effects Damage Functions

Economists Robert J. Anderson, Jr., and Thomas D. Crocker, using statistical analysis, have found a negative correlation between particulate and SO₂ concentrations and residential property values. The statistical results of the Anderson and Crocker regression analysis for the Washington, D. C. SMSA are summarized in Table 2.4-1.

The Anderson-Crocker functions (i.e., the four types of regression equations) actually provide an estimate of market effects resulting from the preference of the residents of the SMSA to live in areas of higher air quality. These market effects result from the conscious and subconscious perception of the direct effects and reflect adjustments made in the marketplace. However, the impact of direct effects on deterioration of materials, etc. are also reflected to a degree in these functions and cannot be separated out.

The RAPA Cost/Benefit Model demonstration has utilized the Anderson-Crocker damage function (Type I regression equation) applied to the Washington, D. C. SMSA (see Section 2.7).

In utilizing property value functions of this type to estimate the social benefits from market effects, the differences between the annualized household property values under the two strategies (illustrated below) must be determined. In practice, these values were produced from the Property Value Module discussed later in this chapter.

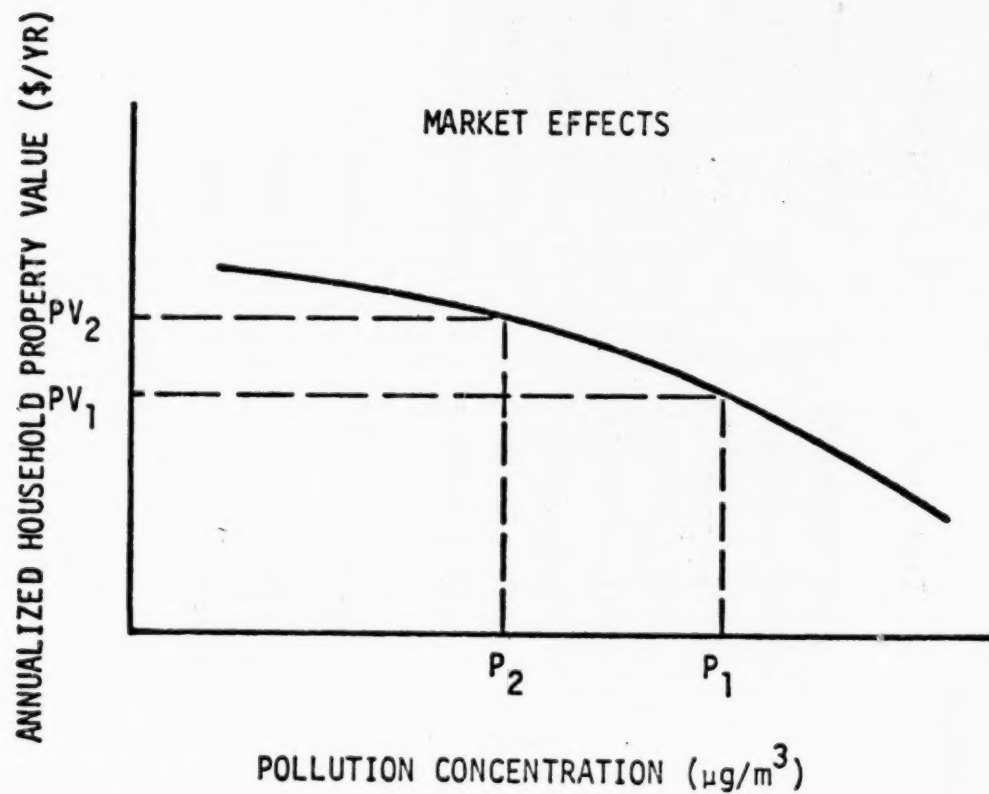
Table 2.4-1. Regression Results of Anderson-Crocker Study *** For The Washington, D. C., SMSA

DEPENDENT INDEPENDENT	Regression Coefficients			
	Type I	Type II	Type III	Type IV
Const.	3.3901 (.4012)	1.1617 (.5622*)	.2428 (.4441**)	.4705 (.3859**)
In (PSN)	-.0712 (.0222)	.0010 (.0270**)	-.0905 (.0239)	-.0727 (.0207)
In (PPT)	-.0610 (.0318**)	-.1698 (.0509)	.0049 (.0316**)	-.0302 (.0275**)
In (MFI)	.7677 (.0447)	.9970 (.0587)	.5109 (.0492)	.4650 (.0431)
In (DLP)	.0044 (.0059**)	.0113 (.0079**)	.0121 (.0055*)	-.0054 (.0048**)
In (OLD)	-.016 (.0103)	-.0213 (.0107*)	-.0606 (.0125)	-.0408 (.0108)
In (NWT)	.0251 (.0064)	.0321 (.0080)	-.0043 (.0066**)	-.0124 (.0058*)
In (DIS)	-.0582 (.0158)	-.0312 (.0097)	-.0216 (.0152**)	-.0111 (.0132**)
In (MRM)		.9064 (.1948)		
R ²	.6966	.7897	.6963	.7549
S ²	.0222	.0179	.0181	.0136
T	275	121	218	218

* * Not significantly different from zero at the .01 level.

** Not significantly different from zero at the .05 level.

*** R. J. Anderson, Jr., and T. D. Crocker, "Air Pollution and Housing: Some Findings" Paper No. 264, Institute for Research in the Behavioral, Economics, and Management Sciences, Purdue University, Lafayette, Indiana, January 1970.



$$\text{SOCIAL BENEFIT} = PV_2 - PV_1$$

2.5 INTERFACE MODULE

The Interface Module (CONVRT) calculates the mean concentrations of particulate matter and sulfur dioxide for each census tract (CTPC) in the air quality control region or standard mean statistical area of interest. The resulting data set(s) of census tract pollutant concentrations (CTPC) and the card deck of census tract attributes provide the only interfaces between the remaining analysis modules of the RAPA Cost/Benefit Model. The relation of the Interface Module to the other modules of the RAPA Cost/Benefit Model is illustrated in Figure 2.5-1.

2.5.1 Input

The receptor point pollutant concentrations are produced in punched card form by the Regional Strategies Segment of IPP (see Section 2.2). A card deck is produced by IPP for each strategy/pollutant combination,

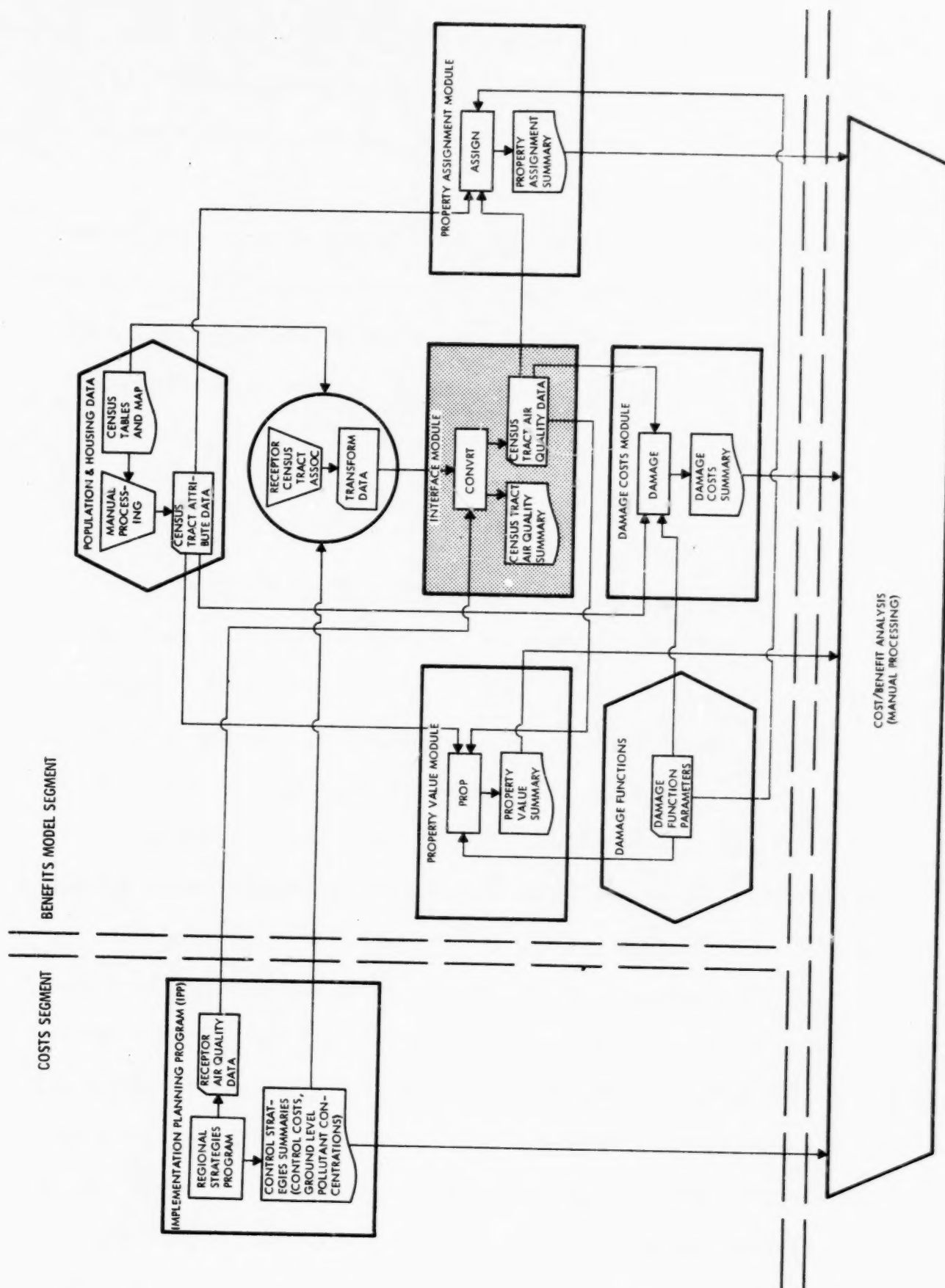


Figure 2.5-1. RAPA Cost/Benefit Model; Interface Module.

and CONVRT processes these decks, one at a time, with the census tract attribute data. However, the capability for multiple runs exists which permits the processing of a number of decks in sequence. The technique for doing this is detailed in Appendix E.

The user must also provide the Interface Module with an association (in punch card form) of specific receptor points with each census tract for purposes of determining the census tract air quality (see Appendix E for card formats). The next sub-section elaborates the analytical techniques used to form the census tract/receptor point association. Figure 2.5-2 indicates the relation of the association procedure in the overall flow of the RAPA Cost/Benefit Model.

2.5.2 Analytical Technique for Estimating Census Tract Air Quality

The Regional Strategies Segment of IPP computes air pollutant concentration values at specified receptor points distributed over the region. Up to 225 regularly spaced receptors may be specified, together with 50 individually located receptors. These receptor locations are used for both particulates and sulfur oxides. The regularly spaced receptors are defined by intersections in a grid pattern having equidistant vertical and horizontal spacing. The grid pattern is determined by the location of its southwest corner (with respect to the origin of the source coordinate system), the number of rows and columns of receptors, and the distance between adjacent rows and columns. Figure 2.5-3 shows the relationship between the receptor points and census tracts for Washington, D. C. The regular grid system (indicated by solid circles) has been divided into a "coarse" system covering the entire SMSA and a "fine" system covering the central city. The individually specified receptors are indicated by empty circles. Figure 2.5-4 is a close-up view of the central city and the "fine" grid system.

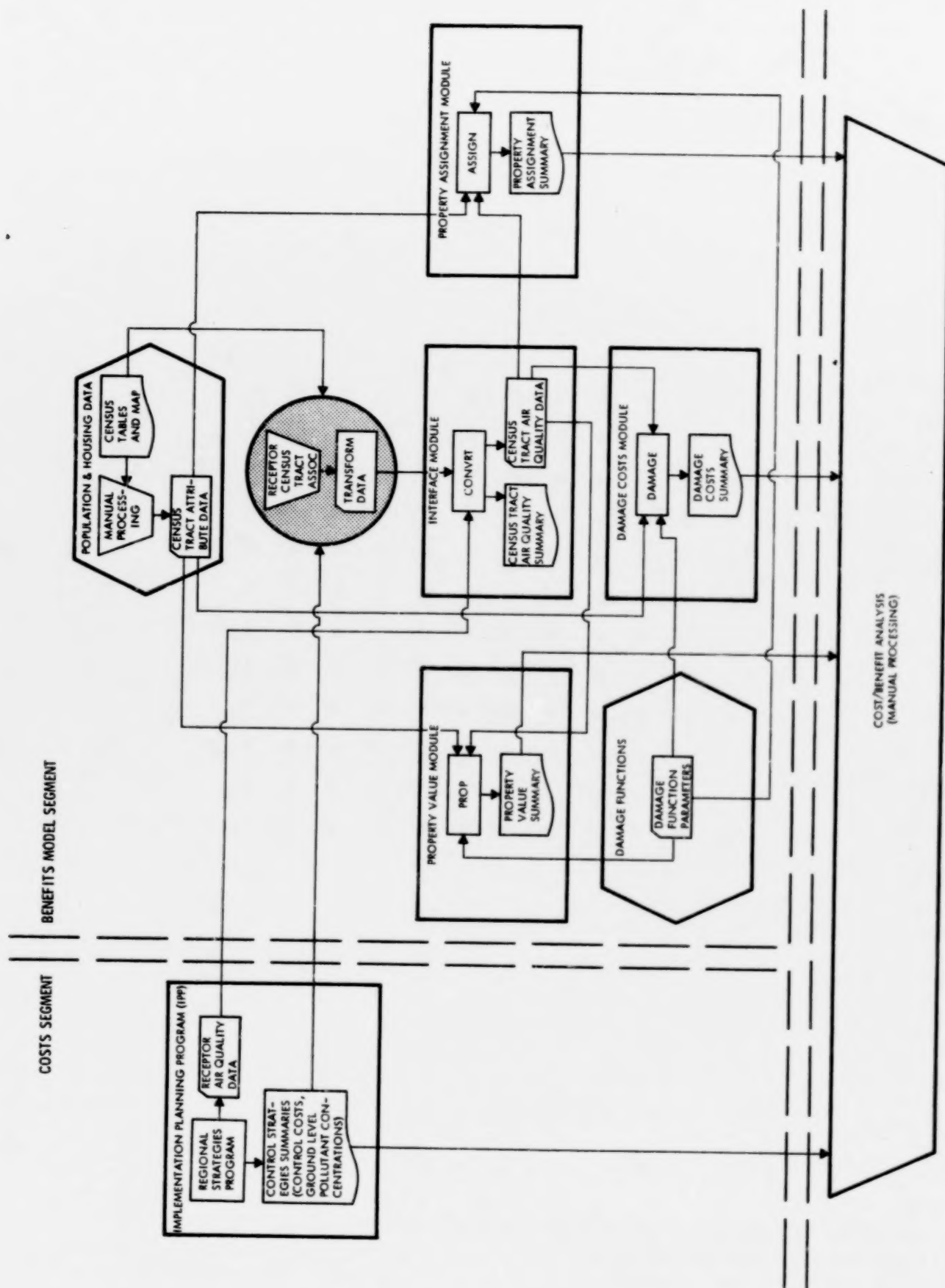
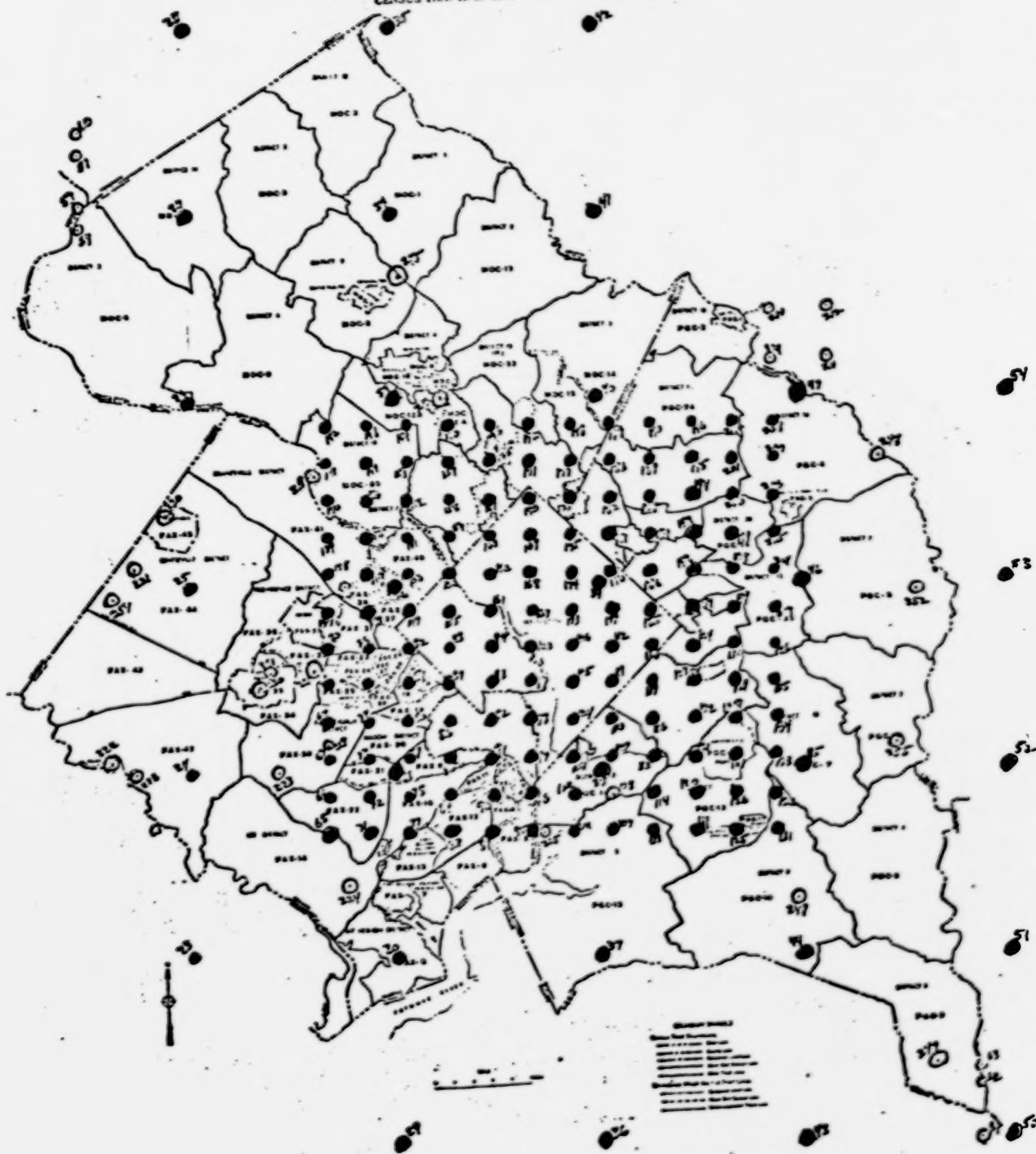


Figure 2.5-2. RAPA Cost/Benefit Model; Receptor Point Census Tract Association.

CENSUS TRACTS IN THE WASHINGTON BASIN



- ⊙ Location of receptor point and receptor point number, XX.
- Regular grid system receptor
- Specially located receptor

Figure 2.5-3. Receptor Points Superimposed on Census Tracts of the NCIAQCR.

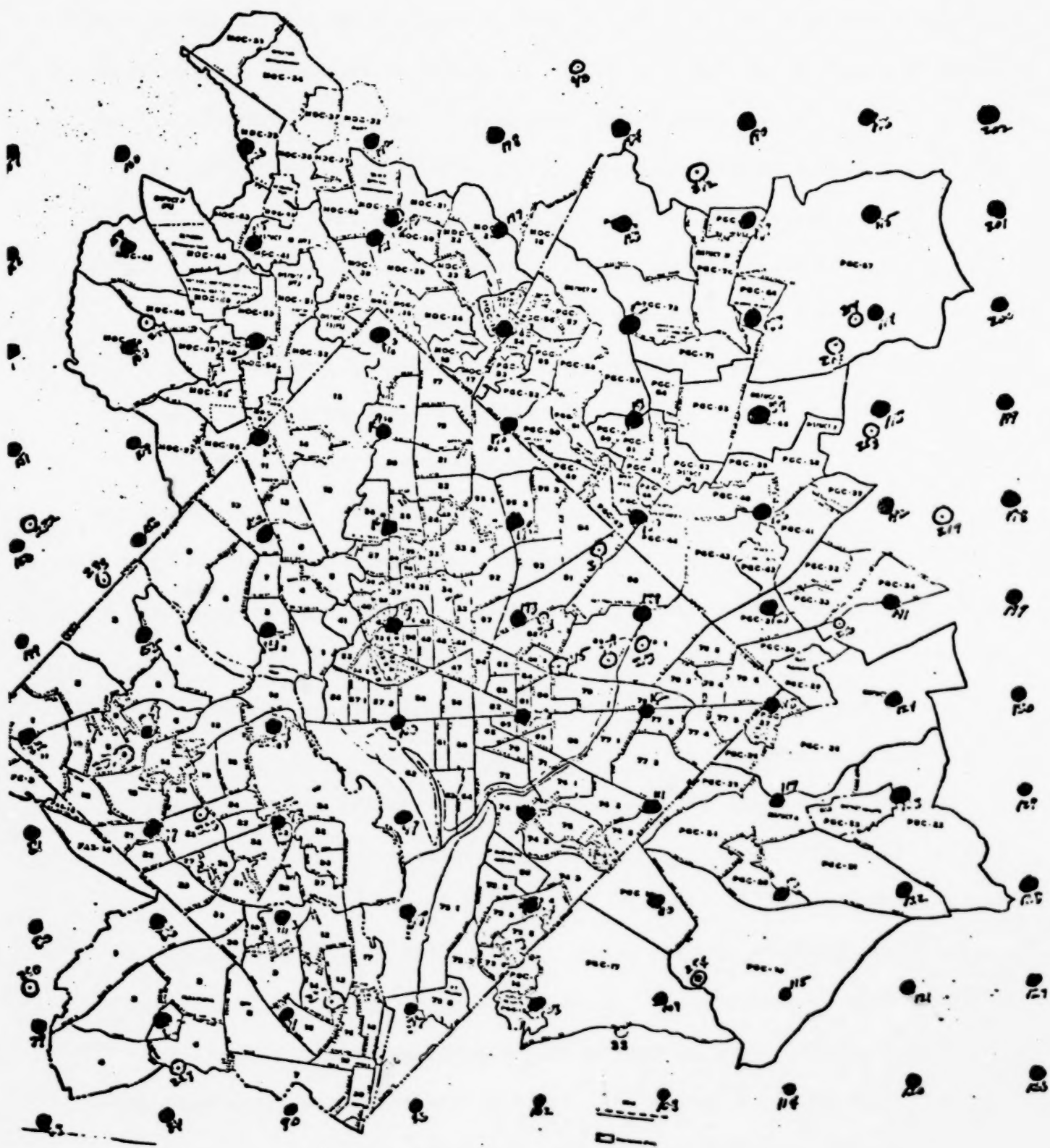


Figure 2.5-4. Receptor Points Superimposed on Census Tracts of the NCIAQCR, Close-Up View of Central City.

A procedure was developed for relating the receptor point pollutant concentration data as calculated by IPP to mean values for the census tracts. These mean values are referred to as the census tract pollutant concentrations (CTPC). It is assumed that these mean values are representative of the actual concentrations anywhere in the census tract, i.e., that the pollutant concentrations are reasonably homogeneous over the area of a census tract. The procedure uses the existing receptor grid of IPP and the census tract data in the format presented in Appendix E.

An obvious procedure would involve re-orienting the receptor grid system so that the receptor coincides with the centroid of each census tract. These centroidal concentration values could then be used to approximate the census tract pollutant concentrations. However, since the number of census tracts generally exceeds the maximum number of 50 individually located receptors, the special multiple run procedures would have to be employed in the Air Pollutant Concentration Segment of IPP in order to build up a sufficient number of special receptors*. These procedures significantly increase costs in operational computer time.

The NCIAQCR, with 1960 census data, requires 362 special receptor points. This number would increase to 650 receptors when the 1970 census data is reported, while a region the size of New York City would require on the order of 3,000 special receptors. Even if an initial redesign of IPP were made to accept up to 275 or more special receptors in a single run of the Air Pollutant Concentration Program, the additional cost of computer time would be excessive. Instead, the analytical procedure described here was developed to form the interface.

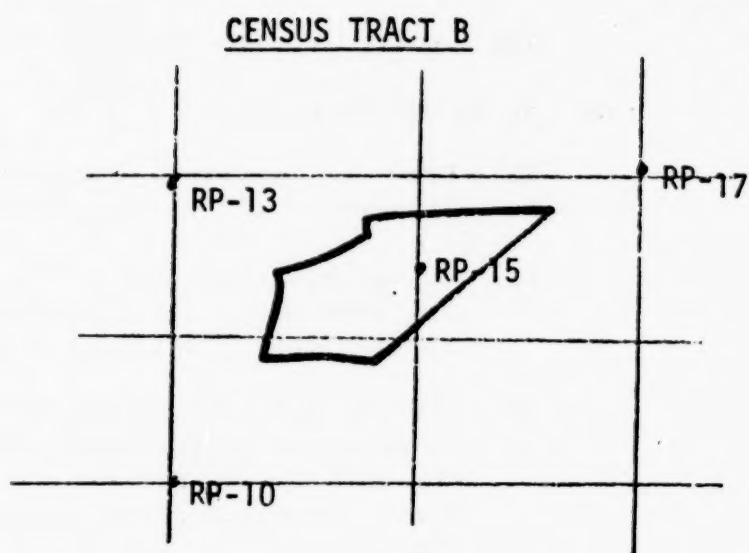
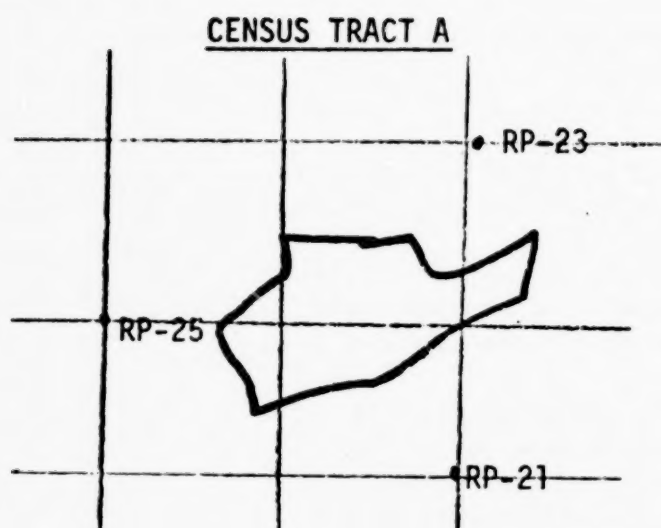
*The procedures for accomplishing this are detailed in Section 3.2 Air Quality Implementation Planning Program, Vol. II.

The method that was employed in determining the CTPC for each census tract is as follows:

- (1) Draw the Universal Transverse Mercator grid system which is used in IPP on the census tract base map for the region.
- (2) Using this reference grid, locate the receptor points on the base map. These receptors locations are provided in the Regional Strategies Segment output (see Section 2.2).
- (3) Examine one census tract and visually determine the combination of receptors that would appear to yield the most representative air quality for the census tract (isopleth plots can provide valuable assistance here).
- (4) List the receptor numbers of the receptor points that were selected for the census tract on a specially prepared data form (Appendix E).
- (5) Calculate the CTPC by taking the arithmetic average of the pollutant concentration values of the selected receptors. This is done for both particulates and sulfur oxides.
- (6) Repeat the process for each census tract in the air quality control region.

This operation is conducted once for each AQCR by the researcher before the cost/benefit analysis of the region is begun. In practice, after the special forms of Step (4), above, have been completed, the information is placed on punch cards (format in Appendix E). Step (5) is then automatically performed by the CONVRT module of the RAPA Cost/Benefit Model.

The six steps of the entire procedure are illustrated below for a hypothetical example. Consider the following two situations:



CONTROL STRATEGY RESULTS:

<u>Receptor Point</u>	<u>Calculated Air Quality ($\mu\text{g}/\text{m}^3$)</u>	<u>Receptor Point</u>	<u>Calculated Air Quality ($\mu\text{g}/\text{m}^3$)</u>
RP-21	78.6	RP-10	97.0
RP-23	79.5	RP-13	98.7
RP-25	77.9	RP-15	97.5
		RP-17	98.2

For Census Tract-A, the researcher will likely choose the three Receptor Points RP-21, RP-23 and RP-25 to represent the census tract. He will then list these receptor points on the prepared form. This same combination of receptor points will be used each and every time a strategy is evaluated using the C/B model. To compute the air quality for Census Tract-A, the following equation is used:

$$(\text{CTAQ})_A = \frac{(\text{AQ})_{21} + (\text{AQ})_{23} + (\text{AQ})_{25}}{n}$$

where:

- $(\text{CTAQ})_A$ = Air quality for Census Tract-A.
- $(\text{AQ})_{21}$, $(\text{AQ})_{23}$, and $(\text{AQ})_{25}$ = Air Quality for the Receptor points RP-21, RP-23, and RP-25, respectively.

- n = Number of receptor points chosen to represent Census Tract-A.

For the example, then, the calculated air quality for Census Tract-A is:

$$(CTAQ)_A = \frac{78.6 + 79.5 + 77.9}{3} = 78.7 \mu\text{g}/\text{m}^3$$

For Census Tract-B, the researcher will probably choose receptor point RP-15 to represent the census tract. Since RP-15 is relatively near the centroid of the census tract, it will likely give a better estimate of the census tract than will any combination of the four receptor points shown. Following the procedure illustrated for Census Tract-A, the calculated air quality will be as follows:

$$(CTAQ)_B = \frac{(AQ)_{15}}{n} = \frac{97.5}{1} = 97.5 \mu\text{g}/\text{m}^3$$

2.5.3 Output

The interface module produces both printed tables and punched card output. The information contained in both is essentially the same, although the formats are different. Figure 2.5-5 shows a sample of the tabulated data produced by CONVRT; it includes the census tract identification, political jurisdiction number (Washington, D.C. = 1, Montgomery County = 2, Prince Georges County = 3, Arlington County = 4, Fairfax County = 5, Alexandria = 6, Falls Church = 7), pollutant concentration (micrograms per cubic meter) and the background concentration value*. In addition, a tabulated summary of the receptor point pollutant concentrations that were supplied as input is available to the user. The output table is optional, and can be suppressed.

* For a discussion of the background pollutant concentration, see Chapter 4. Air Quality Implementation Planning Program, Vol. I.

CENSUS TRACT POLLUTANT CONCENTRATIONS -- OUTPUT			
WASHINGTON, D.C., EXISTING -- SULFUR DIOXIDE			
BACKGROUND = 20.00 (MICROGRAMS PER CUBIC METER)			
NUMBER	POLITICAL JURISDICTION	CENSUS TRACT	POLLUTANT CONCENTRATION (MICROGRAMS PER CUBIC METER)
1	1	1	64.79
2	1	2	61.08
3	1	3	61.04
4	1	4	63.34
5	1	5	65.33
6	1	6	56.88
7	1	7	58.94
8	1	8	56.65
9	1	9	56.04
10	1	10	56.88
11	1	11	51.77
12	1	12	56.88
13	1	13	61.63
14	1	14	58.58
15	1	15	55.22
16	1	16	63.78
17	1	17	
18	1		
19	1		
20			
21			
22			

Figure 2.5-5. Output Format-Tabulated Census Tract Pollutant Concentration Data.

2.6 DAMAGE COSTS MODULE

The Damage Costs Module (DAMAGE) illustrated in Figure 2.6-1 employs a general purpose linear damage function to calculate annual damage costs on a per capita basis as a function of pollutant concentration. A separate function is used for particulates and sulfur oxides, but the general form is the same:

$$d_c = A_1 \times \text{CTPC} + A_0, \quad (2.1)$$

where d_c is the annual per capita damage cost (dollars/year)

CTPC is the census tract pollutant concentration

(A_0, A_1) are coefficients which are provided to the program and vary with the pollutant (particulates or SO_2).

The total damage cost on a census tract basis is then calculated from:

$$D_c = \text{POP} \times d_c, \quad (2.2)$$

where D_c is the census tract damage cost (dollars/year) on an annual basis

POP is the total population of the census tract.

The coefficients (A_0, A_1) provide a measure of the costs of damage to the physical health of the population, residential property, materials and vegetation. A discussion of the Pro Forma Damage Functions used in the NCIAQCR demonstration and their derivation is provided in Appendix C.

The program can be easily modified to accept a general polynomial damage function of the form:

$$d_c = A_0 + A_1 \times \text{CTPC} + A_2 \times (\text{CTPC})^2 + \dots + A_N \times (\text{CTPC})^N,$$

where all the coefficients ($A_0, A_1, \dots, A_N$) and the order of the polynomial, N , are provided as input data. This will probably become a desirable modification in the future, as more research is done on damage

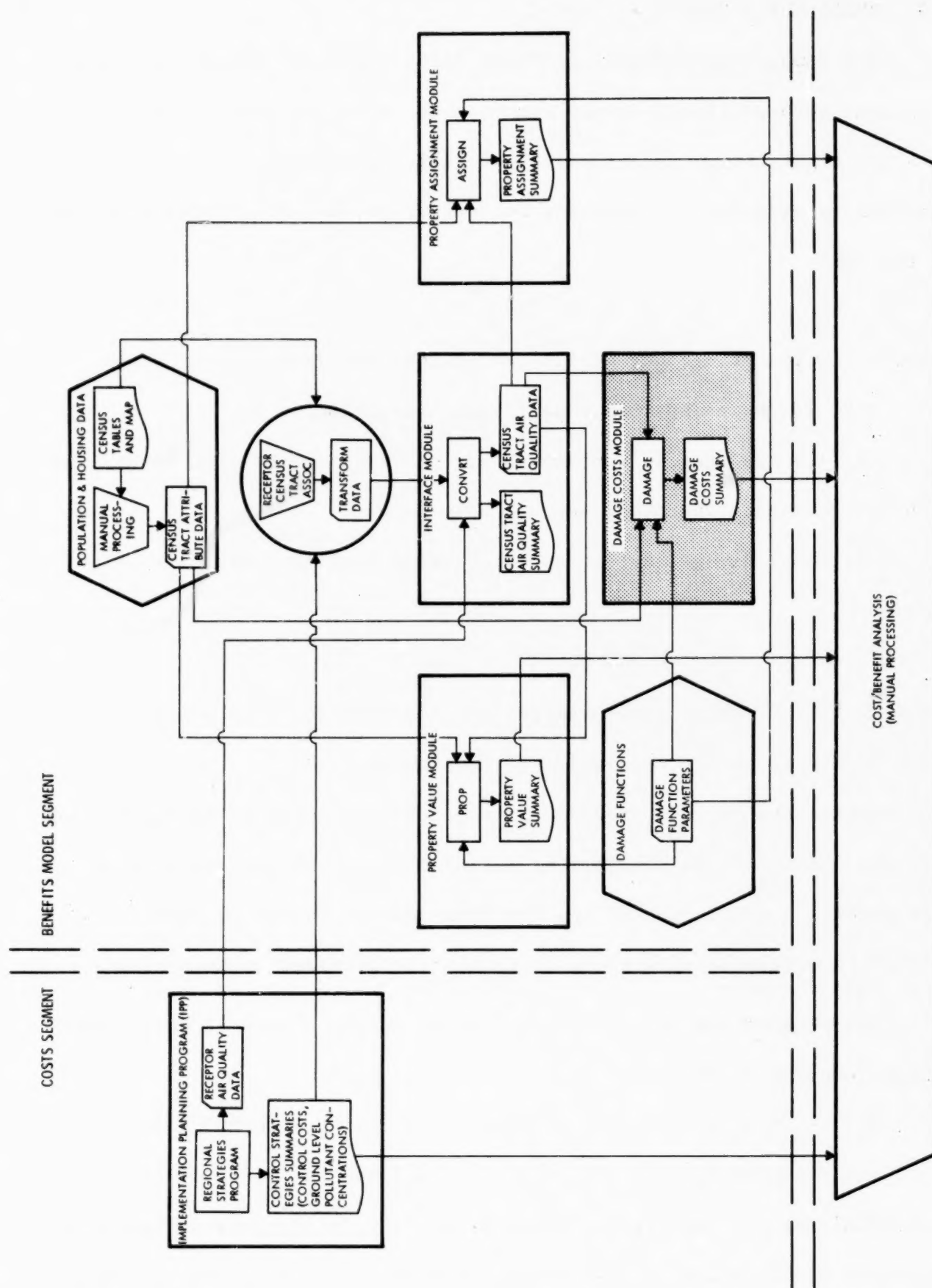


Figure 2.6-1. RAPA Cost/Benefit Model; Damage Costs Module.

functions. However, the linear form incorporated into the existing module is adequate for the state-of-the-art.

2.6.1 Input

The Damage Costs Module requires the following inputs:

- (1) The slope and intercepts (A_1 , A_0) for the linear damage function. The input is in the form of a punched card (format in Appendix).
- (2) The card deck of census tract attributes for the region. This deck contains all the census tract attributes listed in Appendix E and provides common input for all of the analysis modules. However, each module reads into core only those attributes required for the particular analysis. DAMAGE only stores the total population and census tract identification numbers.
- (3) The census tract pollutant concentration data deck produced by the interface module.

These inputs are required separately in separate runs for each pollutant/strategy combination.

2.6.2 Output

The output of the Damage Costs Module includes two tabulated summaries of the input data:

- (1) Census tract attributes (identification number and total population).
- (2) Census tract pollutant concentrations.

Both of these input data summaries are optional and can be suppressed.

The principal output consists of tabulated values of exposure and damage costs for each census tract identified by number and political

jurisdiction. The damage costs in dollars per year are calculated from equation (2.2). The exposure, E_i , of census tract "i" is defined as:

$$e_i = \text{CTPC}_i \times \text{POP}_i \quad (2.3)$$

(people-micrograms per cubic meter)

For each political jurisdiction, total and arithmetic averages are given for the damage costs and exposure, i.e., the following quantities:

totals,

$$\sum_{i=1}^{\text{NPJ}} D_{ci}, \quad \sum_{i=1}^{\text{NPJ}} e_i, \quad (2.4)$$

averages

$$\frac{1}{\text{NPJ}} \sum_{i=1}^{\text{NPJ}} D_{ci}, \quad \frac{1}{\text{NPJ}} \sum_{i=1}^{\text{NPJ}} e_i, \quad (2.5)$$

where NPJ is the total number of census tracts in the political jurisdiction. An additional quantity, the pollutant concentration weighted with respect to population, $\overline{pc}$, is given for each political jurisdiction. This quantity is calculated:

$$\overline{pc} = \frac{\sum_{i=1}^{\text{NPJ}} e_i}{\sum_{i=1}^{\text{NPJ}} \text{POP}_i} \quad (2.6)$$

The corresponding quantities for (2.4), (2.5) and (2.6) are also given on a region-wide basis, i.e., the summations are performed over all census tracts. Figure 2.6-2 shows a sample of this damage costs summary output.

CENSUS TRACT DAMAGE COST				
WASHINGTON, D.C., EXISTING -- SULFUR DIOXIDE				
NUMBER	POLITICAL JURISDICTION	CENSUS TRACT	EXPOSURE	DAMAGE COST
324	5	26	185797.	98909.
325	5	27	232448.	124273.
326	5	28	208235.	111328.
327	5	29	248271.	132194.
328	5	30	254824.	134796.
329	5	31	251868.	133702.
330	5	32	227976.	120613.
331	5	33	552622.	237224.
332	5	34	160903.	85782.
333	5	35	607554.	320812.
334	5	36	180097.	94668.
335	5	37	271203.	143304.
336	5	38	383478.	209227.
337	5	39	403500.	216000.
338	5	40	282928.	151712.
339	5	41	206053.	108635.
340	5	42	178903.	93191.
341	5	43	108656.	57795.
342	5	44	156264.	81588.
343	5	45	83247.	43375.
45	POLITICAL JURISDICTION TOTALS		12544913.	6731982.
	POLITICAL JURISDICTION AVERAGES		278776.	149600.
	POLITICAL JURISDICTION AIR QUALITY		47.82	(WEIGHTED W.R.T. POPULATION)
344	6	1	138313.	75245.
345	6	2	121194.	66386.
346	6	3	181645.	99144.
347	6	4	20184.	10832.
348	6	5	323459.	176620.
349	6	6	193457.	105634.
350	6	7	135892.	74591.
351	6	8	340450.	196712.
352	6	9	303042.	168438.
353	6	10	245716.	137717.
354	6	11	389754.	218446.
355	6	12	523013.	295029.
356	6	13	250777.	136341.
357	6	14	257125.	139793.
358	6	15	242752.	133439.
359	6	16	263378.	141493.
360	6	17	56799.	31432.
361	6	18	342126.	187932.
362	6	19	146136.	77454.
363	6	20	421781.	231987.
20	POLITICAL JURISDICTION TOTALS		4896983.	2695037.
	POLITICAL JURISDICTION AVERAGES		244849.	134752.
	POLITICAL JURISDICTION AIR QUALITY		53.81	(WEIGHTED W.R.T. POPULATION)
364	7	1	113179.	60612.
365	7	2	270555.	144533.
366	7	3	98520.	53020.
3	POLITICAL JURISDICTION TOTALS		482254.	258169.
	POLITICAL JURISDICTION AVERAGES		160751.	96056.
	POLITICAL JURISDICTION AIR QUALITY		47.33	(WEIGHTED W.R.T. POPULATION)
366	REGIONAL TOTALS		129200000.	73551808.
	REGIONAL AVERAGES		353005.	200961.
	REGIONAL AIR QUALITY		65.05	(WEIGHTED W.R.T. POPULATION)

Figure 2.6-2. Sample Damage Costs Summary Output

2.7 PROPERTY VALUE MODULE

The Property Value Module (PROP) calculates residential property values using the Anderson-Crocker regression equation [Anderson and Crocker, 1970]. The relation of PROP in the flow of the RAPA Cost/Benefit Model is shown in Figure 2.7-1. This equation is a multi-linear function of the form

$$\begin{aligned} \ln (PV) = & a + b \ln (PSN) + C \ln (PPT) + d \ln (MFI) \\ & + e \ln (DLP) + f \ln (OLD) + g \ln (NWT) \\ & + H \ln (DIS) + i \ln (MRM). \end{aligned} \quad (2.7)$$

PV is the average residential property value per household in the census tract, of which the module calculates four types:

- Type I - Median property value of owner occupied housing (MPV) is calculated for all census tracts having more than one person per acre (see Table B.1-1 in Appendix B for explanation of MPV).
- Type II - Median property value of owner occupied housing (MPV) is calculated for all census tracts having more than one person per acre and for which single family residential units constitute at least 75% of all housing units.
- Type III - Median gross rent of renter occupied housing (MGR) is calculated for all census tracts having more than one person per acre (see Table E.1-1 in Appendix E for explanation of MGR).
- Type IV - Median contract rent of renter occupied housing (MCR) is calculated for all census tracts having more than one person per acre (see Table B.1-1 in Appendix B for explanation of MCR).

The independent variables:

- DIS - Distance of census tract from central business district (intersection of Pennsylvania Avenue and K Street in Washington, D. C.).
- DLP - Number of dilapidated housing units.
- MFI - Mean family income.

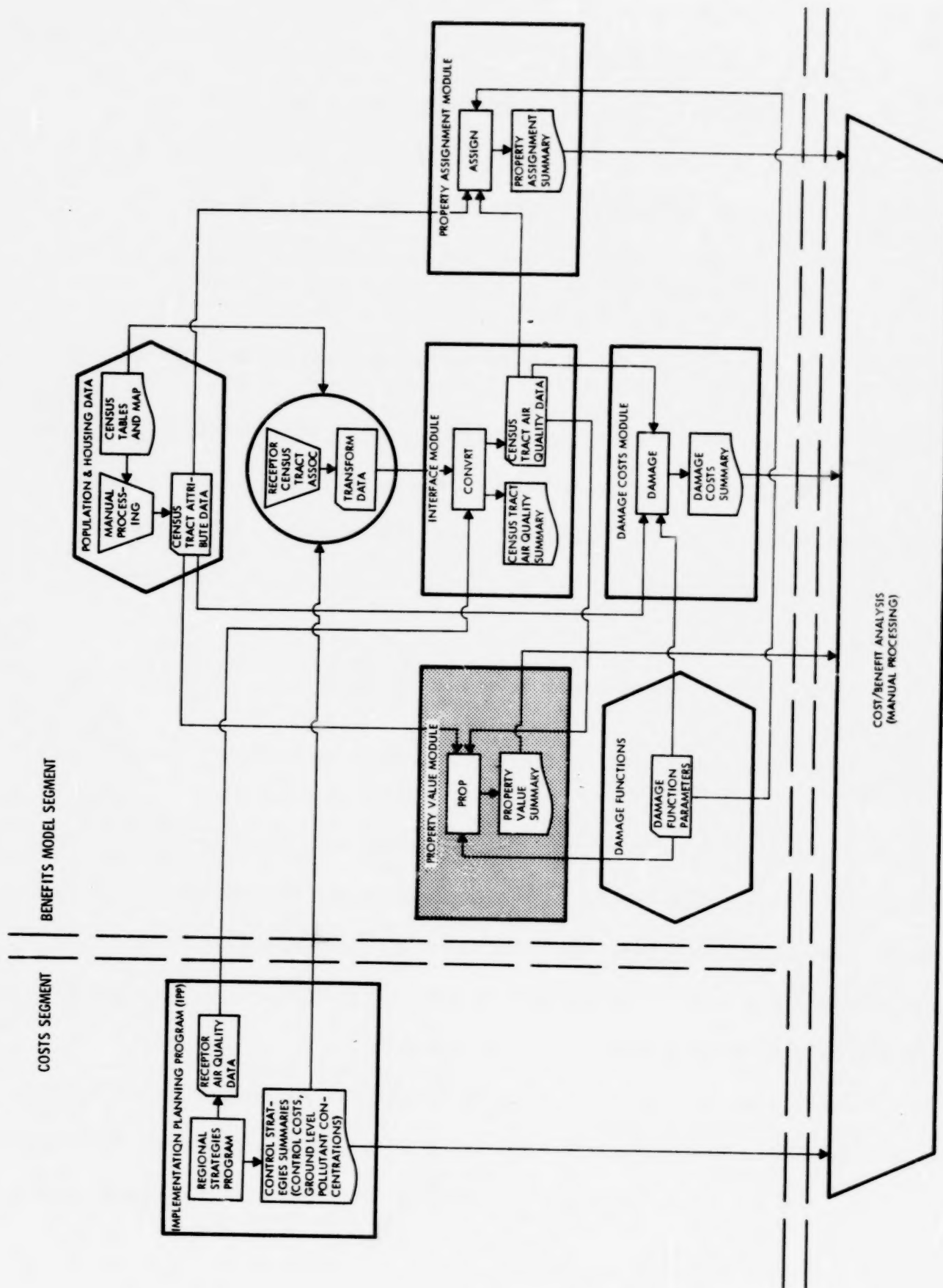


Figure 2.7-1. RAPA Cost/Benefit Model; Property Value Module.

- MRM - Median number of rooms in a housing unit.
- NWT - Number of housing units occupied by nonwhite.
- OLD - Number of housing units over ten years old in 1959.

are all included in the list of census tract attributes in Table B.1-1, Appendix B. The two remaining variables in equation (2.7) are:

- PPT - Annual arithmetic mean suspended particulates, i.e., the particulate concentration as calculated by CONVRT (micrograms per cubic meter).
- PSN - Annual arithmetic mean sulfation (milligrams per 100 square centimeter).

The CONVRT module supplies the annual average SO_2 concentration (at ground level) in micrograms per cubic meter. Consequently, there is a need to convert these values to the sulfation rate (made by the lead peroxide candle or plate technique). This is accomplished through the following relations:

$$\text{Average } \text{SO}_2 \text{ Concentration (parts per million)} = K \times \text{sulfation rate } (\mu\text{g}/100\text{cm}^2)$$

$$\text{Average } \text{SO}_2 \text{ Concentration } (\mu\text{g}/\text{m}^3) = 2660 \times \text{average } \text{SO}_2 \text{ Concentration (parts per million)}$$

K is the sulfation rate constant. Experimental data indicates that K is a function of temperature, humidity, other pollutants present and other factors. However, the functional dependence is unknown. On the basis of published data, $0.020 \leq K \leq 0.050$. A commonly accepted value (used in this study) is just the median of this range, i.e., $K = 0.035$.

The coefficients (a,b,c,d,e,f,g,h,i) are the regression coefficients. These values have been determined by Anderson and Crocker for the Washington, D.C. SMSA, the St. Louis SMSA and the Kansas City SMSA using a least squares

regression analysis of the 1960 census data and 1967 air quality data.

This temporal mismatch is a deficiency. However, 1970 census data will not be published for a year or so and 1960 air quality data is non-existent.

In fact, the 1967 data* is itself minimal and coarse compared to the census tract scale. The sulfation, for example, is given in only four levels:

- $<0.6 \mu\text{g}/100\text{cm}^2\text{-day}$
- 0.6 - 1.0
- 1.1 - 1.5
- >1.5 .

The baseline (Existing) conditions in the present analysis employed 1969 air quality data.

The existing version of PROP does not determine the regression coefficient independently; these must be supplied as input data. A desirable addition to the RAPA Cost/Benefit Model at some future date would be a Regression Analysis Module which would accept the census tract attributes and contemporaneous (i.e., existing) air quality data and calculate the values of the coefficients by the method of least squares.

The independent variables of equation (3.7) include only a few of the census tract attributes listed in Table 2.3-1.

Anderson and Crocker did perform regression analyses on a number of other potentially significant parameters, including crime rate, tax rates, per capita school expenditures, measures of neighborhood homogeneity with

*Implementation Plan for Controlling Sulfur Oxide and Particulate Air Pollutants. Prepared for Health Services Administration, Department of Human Resources, Government of District of Columbia, Contract No. 70170, TRW Systems Group.

respect to educational level and occupation, educational attainment measures, population and residential unit density, proportion of units in each tract having basements, etc. These additional variables were found not to be statistically significant for the purposes of property value.

As might be expected, the coefficients b and c of the pollutants were found to be negative in all cases. Consequently, the Anderson-Crocker equation is a type of damage function for residential property values.

2.7.1 Input

The input data elements required by the program are as follows:

- (1) Census tract attribute deck - the only attributes read by PROP are census tract number, POP, MIL, SFH, ALL, MPV, MGR, MCR, MFI, DLP, OLD, NWT, and MRM.
- (2) Census tract pollutant concentrations for both SO_2 and particulates, i.e., a pair of strategy/pollutant concentration decks must be input.
- (3) Sulfation factor, K (card input, format in Appendix).
- (4) Four sets of regression coefficients (a,b,...,h,i) for the Anderson-Crocker property value equation. One set is required for each of the four types of property value (input card formats in Appendix F).

2.7.2 Output

The output consists of three optional (surpressed through JCL) summaries of:

- (1) The Anderson-Crocker equations for the four property value types.
- (2) Census tract attributes listed in Subsection 2.7.1 above.
- (3) The SO_2 and particulate concentrations for each census tract, identified by census tract number and political jurisdiction.

The principal output consists of a tabulation of the four types of property value, listed by census tract (identified by census tract number and political jurisdiction). However, if a census tract does not have at least one person per acre, it is entirely excluded from the listing. If the remaining census tracts do not meet the criteria for any of the other three types of property value, then a value of zero is entered for that property value. The table also includes the values for the exposure in units of people-micrograms per cubic meter. The exposure is given for both SO₂ and particulates. As in the output of the Damage Costs Module, totals and arithmetic averages of the exposures are given on a political jurisdiction and regional basis. The average pollutant concentrations, weighted with respect to population for each political jurisdiction and the region are also given. In addition, political jurisdictions and regional totals and averages of all four property values are included. A sample of this output table is shown in Figure 2.7-2.

For Types I and II property values, the political jurisdiction weighted averages are calculated from:

$$\overline{PV} = \frac{\sum_{i=1}^{NPJ} PV_i \times OWN_i}{\sum_{i=1}^{NPJ} OWN_i} \quad (2.8)$$

where

NPJ = number of census tracts in the political jurisdiction (for regional averages, sums are taken over all census tracts in the region).

OWN = number of owner occupied housing units in the census tract (see Table B.1-1, Appendix B).

CENSUS TRACT PROPERTY VALUE									
WASHINGTON, D.C.									
NUMBER	POLITICAL JURISDICTION	CENSUS TRACT	EXPOSURE SULFUR DIOXIDE	EXPOSURE PARTICULATES	PROPERTY VALUE TYPE 1	PROPERTY VALUE TYPE 2	GROSS RENT TYPE 3	CONTRACT RENT TYPE 4	
355	6	12	523013.	593023.	20350.	0.	78.	63.	
356	6	13	250777.	330677.	20286.	45304.	84.	64.	
357	6	14	257125.	339049.	19766.	0.	82.	65.	
358	6	15	242752.	278228.	20565.	50491.	87.	72.	
359	6	16	263378.	356825.	13912.	27267.	60.	46.	
360	6	17	56798.	70952.	20710.	0.	89.	69.	
361	6	18	342126.	509145.	17237.	0.	69.	52.	
362	6	19	146136.	203895.	17641.	0.	74.	55.	
363	6	20	421781.	473076.	21098.	0.	78.	58.	
17	POLITICAL JURISDICTION TOTALS		4307625.	5159936.	129845216.	166420192.	1140867.	876339.	
	POLITICAL JURISDICTION AVERAGES		253390.	303526.	20531.	48617.	81.	62.	
	POLITICAL JURISDICTION AIR QUALITY		53.71	64.34	(WEIGHTED WITH RESPECT TO POPULATION)				
364	7	1	113179.	134237.	22945.	62874.	96.	78.	
365	7	2	270555.	319118.	22866.	56494.	132.	90.	
366	7	3	98520.	116086.	30688.	103063.	157.	108.	
3	POLITICAL JURISDICTION TOTALS		482254.	569442.	43564656.	122922832.	140010.	96892.	
	POLITICAL JURISDICTION AVERAGES		160751.	189814.	24887.	70221.	132.	91.	
	POLITICAL JURISDICTION AIR QUALITY		47.33	55.89	(WEIGHTED WITH RESPECT TO POPULATION)				
273	REGIONAL TOTALS		108290468.	115082576.	5329461248.	9515683840.	18381312.	14288155.	
	REGIONAL AVERAGES		396668.	421548.	22365.	66579.	75.	58.	
	REGIONAL AIR QUALITY		66.73	70.92	(WEIGHTED WITH RESPECT TO POPULATION)				

Figure 2.7-2. Sample Output, Property Value Module

For Types III and IV property values, the political jurisdiction weighted averages are calculated from:

$$\overline{PV} = \frac{\sum_{i=1}^{NPJ} PV_i \times RENT_i}{\sum_{i=1}^{NPJ} RENT_i} \quad (2.9)$$

where

RENT = number of renter occupied housing units in the census tract
(see Table B.1-1, Appendix B).

2.8 PROPERTY ASSIGNMENT MODULE

The Property Assignment Module (ASSIGN) determines census tract residential property values under different conditions of ambient air quality. The role of the Property Assignment Module in the RAPA Cost/Benefit Model is illustrated in Figure 2.8-1. The technique developed for the Property Assignment Module is an extension of the analysis employed in the Property Value Module*.

Anderson considered the problem of correctly applying the Anderson-Crocker regression equations for purposes of determining the benefits from improved air quality resulting from a regional control strategy. He states that, "...the appropriate course of action is to treat property values as though they appropriately measure the net productivity of each location and to consider the whole land market in each (location) for which benefits are to be estimated, whether or not...ambient air concentrations change for all locations in the land market." If a given control strategy produces no changes in air quality for a given census tract, then (other independent variables remaining fixed) the property values of that tract, as computed from the Anderson-Crocker equations, will remain unchanged. Consequently, the direct application of incremental benefits to census tracts computed from these regression equations (i.e., from the Property Value Module), will probably understate the benefits from improved air quality. Anderson observes that this direct method does not account for the shifts that will take place in housing markets and only represents "the short-term benefits"

*Based on a procedure proposed by Robert J. Anderson - Private Communication.

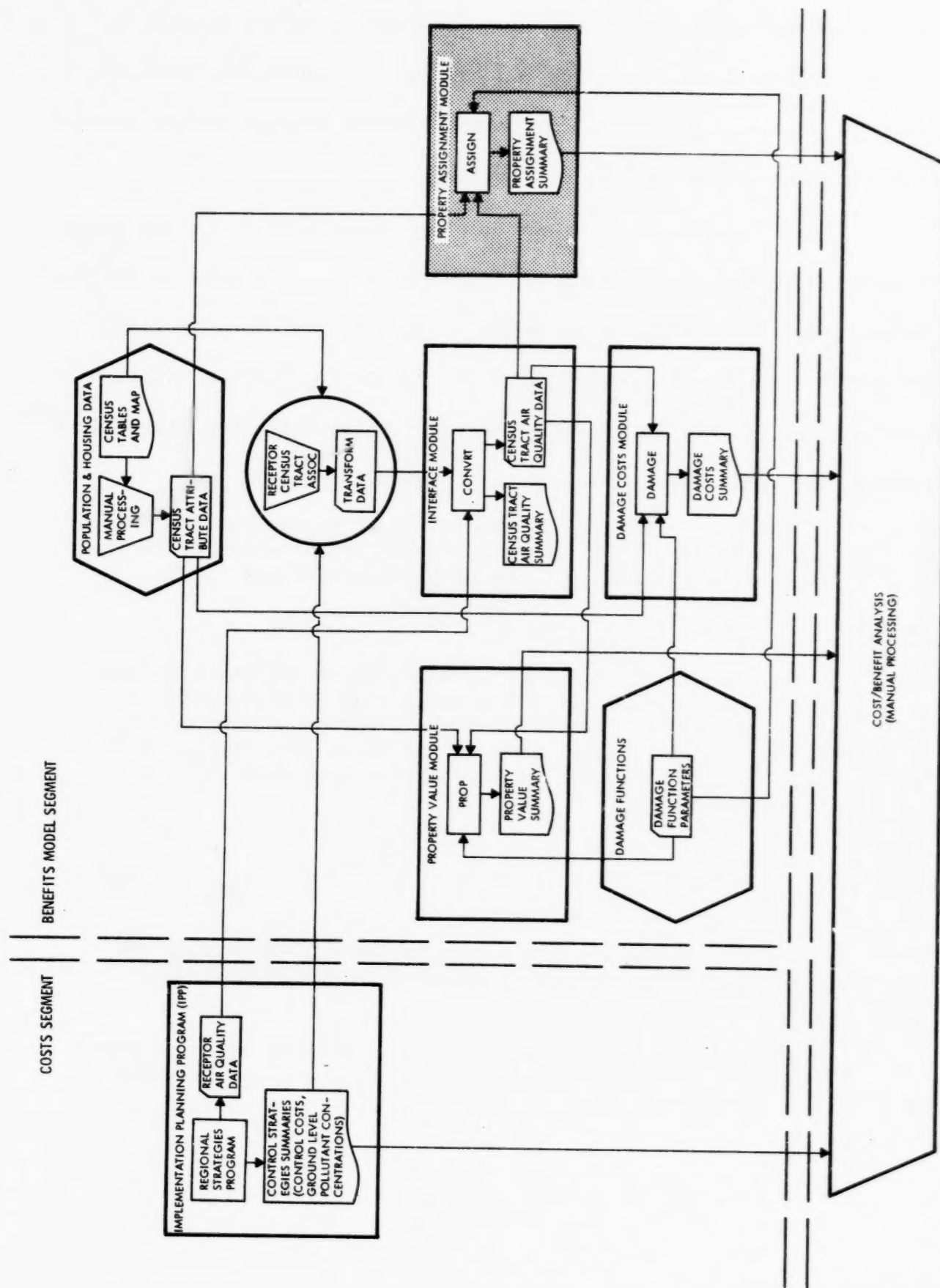


Figure 2.8-1. RAPA Cost/Benefit Model; Property Value Assignment Module.

(i.e., the benefits that result before the housing market has reached a state of equilibrium after the improvement of air quality). Therefore, a procedure to predict the dynamic movements in the housing market that result from improved air quality is required.

The method suggested by Anderson is an assignment technique where the household which is the highest bidder for a property will be assigned that property. He based his procedure on the theoretical principles developed by Robert Lind in a paper "Land Market Equilibrium and the Measurement of Benefit From Urban Programs," illustrates the appropriate procedure for assigning households to properties*:

"Let the relationship between property value, p , income (I), and pollution (s) be given by the following equation (which is similar in form to those in Anderson-Crocker (1970)

$$p = I/s$$

and consider a land market in which there are two locations and two households. Let the households be designated respectively as '1' and '2' and the locations designated as 'a' and 'b'. Let the three tables below give the initial pollution and land market equilibrium situation in this hypothetical AQCR.

				Bids		
	I		s		a	b
1	6	a	1	1	6	3
2	10	b	2	2	10	5

Assigning unoccupied properties to the highest bidder who does not occupy some other property, equilibrium prices are circled.

Now consider an air pollution control program which lowers the level of pollution for location 'b' to .5. The bids and equilibrium are

				Bids	
		a		b	
1		6		12	
6	10			20	

* Private Communication - R. J. Anderson "Comments on Estimating the Benefits of Air Pollution Control Based On Property Value Studies of Anderson and Crocker."

Calculating net benefits as the sum of the differences in net productivity for household 1 and 2 between the two equilibria, we have

$$(6 - 3) + (20 - 10) = 13$$

Suppose we had not calculated this new equilibrium using the assignment problem model, but had instead for each location multiplied the change in pollution by the marginal damage reduction. Since pollution didn't change at 'a' we would have estimated zero benefits for 'a' and benefits of approximately 10 for 'b', or total benefits of 10. By not allowing activities to relocate, through the equilibrium model, so as to maximize their productivity, we reduce estimated benefits."

Based on this simple example due to Anderson, a technique was developed for determining "the equilibrium benefits" for the entire air quality control region. This method is now employed in the Property Assignment Module of the RAPA Cost/Benefit Module.

2.8.1 Determination of Equilibrium Property Values in the Property Assignment Module

The following describes the principles employed in determining the equilibrium property values, from the Anderson-Crocker Regression Equation for all census tracts in a given air quality control region. However, the description is for conceptual purposes only. Efficiency considerations of computer storage and computation time as well as the desired form of the output resulted in the programming of an entirely different algorithm for the Assignment Module. This algorithm, which involves a series of sorts, can be extracted from the FORTRAN program listing (Appendix E).

Consider the Anderson-Crocker Regression Equation:

$$\begin{aligned} \ln PV = & a + b \ln (PSN) + c \ln (PPT) + d \ln (MFI) \\ & + e \ln (DLP) + f \ln (OLD) + g \ln (NWT) \\ & + h \ln (DIS) + i \ln (MRM) \end{aligned}$$

All the independent variables except NWT (percent of housing occupied by nonwhites) and MFI (mean family income) are physical descriptors of the census tract and of more less permanent structures. These descriptors remain fixed to the census tract. MFI, on the other hand is a characteristic of the residents (or households) who can move about between census tracts (or out of the region entirely). NWT is a characteristic of the residents to be sure, but its role is more ambiguous. It may be argued that NWT is also a characteristic of the census tract. While NWT does change for a given census tract, these shifts generally develop over a longer time scale than is characteristic of the movement of individuals. Factors such as Group Cohesiveness, valid discrimination, occupational specialties, etc. contribute "inertia" to NWT. Consequently, for the purposes of the present study, it has been considered as a property of the census tracts themselves.

We next form the dummy variable, DV, given by the relation:

$$\ln (DV) = \ln (PV) - d \ln (MFI) \quad (2.10)$$

DV is essentially a property of the census tracts (i.e., independent of household).

Noting that equation (2.9) is equivalent to

$$DV = \frac{PV}{(MFI)^d} \quad (2.11)$$

We next form the row matrix:

$$\bar{Y} = [DV_1, DV_2, \dots, DV_N], \quad (2.12)$$

by calculating DV for all N census tracts in the region, and sorting, so that:

$$DV_1 > DV_2 > \dots > DV_N. \quad (2.13)$$

Similarly, we form the column vector:

$$\bar{X} = \begin{bmatrix} (MFI_1)^d \\ (MFI_2)^d \\ \vdots \\ (MFI_N)^d \end{bmatrix}; \quad (2.14)$$

by calculating $(MFI)^d$ for all N census tracts, and sorting, so that:

$$MFI_1 > MFI_2 > \dots > MFI_N. \quad (2.15)$$

The square matrix PV_{ij} is then calculated:

$$\overline{DV} = \bar{X} \times \bar{Y} = \begin{bmatrix} PV_{11} & PV_{12} & \dots & PV_{1N} \\ PV_{21} & PV_{22} & \dots & PV_{2N} \\ PV_{N1} & PV_{N2} & & PV_{NN} \end{bmatrix} \quad (2.16)$$

and the elements are given by:

$$PV_{ij} = X_i Y_j = PV_j \left(\frac{MFI_i}{MFI_j} \right)^d \quad (2.17)$$

It is clear that, the diagonal elements ($i = j$) represent property values calculated from the Anderson-Crocker equation:

$$PV_{ii} = PV_i, \text{ and that}$$

$PV_{11} > PV_{22} > \dots > PV_{NN}$. The first diagonal element PV_{11} , in fact, represents

the value obtained from matching the highest mean family income with the highest valued tract (i.e., highest value of DV). Similarly, the second element PV_{22} in the diagonal represents the second highest MFI in the region combined with the second highest valued tract, etc.

These quantities represent the equilibrium property values attained by assuming complete free mobility of households and allowing highest income families to bid on the highest valued property in the marketplace un-encumbered by other considerations.

The Assignment Module calculates the Type I property values of all census tract based on these equilibrium conditions*. These values are also referred to as "bids after shift." The module also calculates the Type I property values without population shifts (i.e., the values calculated in the Property Value Module). These are also referred to as "bids before shift."

2.8.2 Input

The input data required by the Assignment Module consists of the following:

- (1) Census tract attributes (card deck). As in the other modules, only specific attributes are read into core; these are census tract numbers, POP, MIL, MPV, MFI, DLP, OLD, NWT, DIS, MRH.
- (2) The sulfation factor K (card format identical with format for Property Value Module).
- (3) Complete set of Type I regression coefficients (card format identical with format for Property Value Module).
- (4) Two census tract pollutant concentration card decks (i.e., a pair of SO_2 and Particulate Strategies).

*The algorithm used here needs further work; see cautionary note in Section 3.3.

2.8.3 Output

The output of the Assignment Module consists of a series of tabulated summaries. These include the optional input data summaries:

- (1) The Type I Anderson-Crocker Regression Equation and coefficients.
- (2) The listing of census tract attributes used by the module, identified by census tract number.
- (3) The census tract pollutant concentrations for SO_2 and particulates, identified by census tract number and political jurisdiction.

The principal output, however, is a tabulated list of property values identified by census tract (census tract number and political jurisdiction).

These property values are:

- (a) The median property value (MPV) for the census tract as provided in the census data (in dollars).
- (b) The property value bid before shift (i.e., Type I property value as calculated in PROP) in dollars.
- (c) The property bid after shift (i.e., the equilibrium value) in dollars.
- (d) The difference in property value bid (bid after shift - bid before shift) in dollars.

In addition, there are totals and averages for each of the four property value outputs. These are provided in both a political jurisdiction and regional basis. A sample of this output table is provided in Figure 2.8-2.

CENSUS TRACT PROPERTY VALUE BIDS							
WASHINGTON, D.C.	NUMBER	POLITICAL JURISDICTION	CENSUS TRACT	MEDIAN PROPERTY VALUE	PROPERTY VALUE BID BEFORE SHIFT	PROPERTY VALUE BID AFTER SHIFT	DIFFERENCE IN PROPERTY VALUE BID
	257	6	6	15899.	20971.	19081.	-1890.
	258	6	7	11396.	17119.	22830.	5711.
	259	6	8	22093.	20628.	22138.	1510.
	260	6	9	23295.	28263.	19839.	-8424.
	261	6	11	23295.	22067.	22220.	153.
	262	6	12	12900.	20350.	21590.	1239.
	263	6	13	12695.	20286.	20983.	697.
	264	6	14	14300.	19766.	18588.	-1177.
	265	6	15	16301.	20565.	11519.	-9046.
	266	6	16	11204.	13912.	28321.	14410.
	267	6	17	23295.	20710.	19808.	-902.
	268	6	18	13494.	17237.	24651.	7414.
	269	6	19	14003.	17641.	24353.	6712.
	270	6	20	16899.	21098.	24713.	3615.
	17	POLITICAL JURISDICTION TOTALS		101321712.	129845216.	138932352.	9087147.
		POLITICAL JURISDICTION AVERAGES		16100.	20531.	21968.	1437.
	271	7	1	18306.	22945.	14677.	-8268.
	272	7	2	18106.	22866.	23507.	641.
	273	7	3	26108.	30686.	23747.	-6941.
	3	POLITICAL JURISDICTION TOTALS		35373824.	43564656.	36821904.	-6742747.
		POLITICAL JURISDICTION AVERAGES		20208.	24887.	21035.	-3852.
	273	REGIONAL TOTALS		4171612416.	5329461248.	4879036416.	-450462720.
		REGIONAL AVERAGES		17506.	22365.	20475.	-1890.

Figure 2.8-2. Sample Output, Assignment Module.

2.9 PROPOSED MODEL ADDITIONS

Experience with the Benefits Model Segment of the RAPA Cost/Benefit Model has already suggested desirable model additions for the future. The highest priority should be given to modifying the program to accept NTIS magnetic tapes.

These tapes offer the same advantage as the census tables, i.e., standardized formats, reliable data, completeness, and consistency between tapes. However, there is the similar problem of preliminary data reduction to obtain the information in the form of the census tract attributes listed in Table B.1-1, Appendix B. However, the data reduction could easily be performed automatically with development of an additional module for the RAPA Cost/Benefit Model. An additional disadvantage, however, is that tapes have been produced according to standard location areas and not standard mean statistical areas. Consequently, to compile complete information for the Washington, D. C. SMSA, for example, would require the acquisition of three NTIS tape reels (PB-170-773, PB-170-779 and PB-170-781). Nevertheless, it is now felt that the advantages here outweigh the disadvantages and that the additional module for the RAPA Cost/Benefit Model should be developed to read NTIS tapes and perform preliminary data processing, if any extensive application of the model beyond the present study is contemplated.

BLANK PAGE

3.0 MODEL DEMONSTRATION

The National Capital Interstate Air Quality Control Region (NCIAQCR) was selected for the demonstration because of the availability of control strategy analysis results from IPP. As has been described in Section 2.0, both IPP and the Benefits Model Segment must be run to provide the basis for a cost/benefit analysis; control costs and air quality estimates come from IPP, and the benefits, measured in dollars, come from the Benefits Model Segment.

In the sections below, the census tract and pollutant concentration data inputs to the Benefits Model Segment which were used in the demonstration are described in detail. The resulting outputs, which describe the direct damage costs, the property value impacts and the property value impacts with market adjustments*, are also described. The interpretation of these results is currently underway and will be the subject of a forthcoming Office of Air Programs report.

3.1 INPUT DATA FOR THE NCIAQCR DEMONSTRATION

The inputs which are common to all three modules in the Benefits Model Segment are described below; those which are specific to a given module are described in subsequent sections, i.e., the damage function inputs are discussed in Section 3.2, Estimation of Direct Damage Costs, and the property value inputs (regression coefficients) are discussed in Section 3.3, Estimation of Property Value Effects.

* As a result of looking at Assignment Model results which were contrary to what was expected, it was realized that an important capability, i.e., that of accounting for the variation in the number of owner occupied dwellings from one census tract to another, has been omitted from the model. This capability is currently being incorporated into the model.

3.1.1 Census Data

The population and housing data for the Washington, D. C. SMSA was based on the 1960 Decennial Census of Population and Housing. The primary source was a magnetic tape prepared as a part of the research described by Anderson and Crocker [1970]. However, certain additions and modifications to these data were made, based on the printed census tables published by the Bureau of the Census [1960]. Figure 3.1-1 presents the complete list of census attributes employed in this study for all 366 census tracts of the Washington, D. C. SMSA (these attributes were defined in Chapter 2.0). Those census tracts for which only population is listed (second column) were input to the DAMAGE Module only, i.e., they failed one or both of the tests which must be passed before a census tract is used as input to the Property Value or Assignment Module.

3.1.2 Pollutant Concentration/Strategy Data

A total of ten strategies were tested in the NCIAQCR cost/benefit demonstration. Half of these applied to the control of particulate emissions and half applied to the control of sulfur dioxide emissions. The pollutant concentration data corresponding to these strategies were originally produced using the prototype version of the Implementation Planning Program (Appendix A) for the Implementation Plan prepared by TRW for the Washington, D. C. Region [TRW, August 1970].

The strategies selected for comparison were:

Particulate Strategies

- Existing Particulates (1970) Air Quality data for particulates under existing conditions throughout the region. The ground level particulate concentration isopleths for this situation are shown in Figure 3.1-2. This provides the baseline for particulate strategies.

CENSUS TRACT ATTRIBUTES -- INPUT														
WASHINGTON, D.C.														
CENSUS TRACT NUMBER	TOTAL POPULATION	AREA IN SQUARE MILES	SINGLE FAMILY HOUSING	ALL HOUSING UNITS	PROPERTY VALUE	MEDIAN GROSS RENT	MEDIAN CONTRACT RENT	MEDIAN FAMILY INCOME	MEDIAN DILAPIDATED HOUSING UNITS	HOUSING OVER 10 YEARS OLD	NONWHITE OCCUPIED HOUSING DISTRICT	DISTANCE TO BUSINESS ROUTES	MEDIAN HOUSING	
0001	5963.	0.	0.	0.	0.	0.	0.	1.	1.	1.	1.	1.0	1.0	
0002	5723.	0.	0.	0.	0.	0.	0.	1.	1.	1.	1.	1.0	1.0	
0003	6412.	301.	1419.	2555.	17801.	96.	92.	867.	1.	2310.	30.	4.0	5.5	
0004	1280.	0.	0.	0.	0.	0.	0.	1.	1.	1.	1.	1.0	1.0	
0005	7295.	0.	0.	0.	0.	0.	0.	1.	1.	1.	1.	1.0	1.0	
0006	5486.	320.	1001.	2262.	23202.	95.	89.	11580.	7.	1986.	76.	3.5	4.7	
0007	8544.	237.	288.	4930.	20090.	111.	109.	10840.	1.	2850.	78.	4.5	3.2	
0008	6235.	0.	0.	0.	0.	0.	0.	1.	1.	1.	1.	1.0	1.0	
0009	6715.	0.	0.	0.	0.	0.	0.	1.	1.	1.	1.	1.0	1.0	
0010	11696.	819.	2317.	5497.	23506.	89.	88.	11092.	1.	4398.	39.	5.5	3.9	
0011	5203.	410.	1310.	1742.	22292.	147.	137.	10373.	2.	1501.	46.	6.0	6.5	
0012	5213.	352.	968.	2208.	23202.	137.	129.	10927.	9.	1561.	41.	5.0	4.4	
0013	7803.	0.	0.	0.	0.	0.	0.	1.	1.	1.	1.	1.0	1.0	
0014	6549.	352.	1592.	2424.	23202.	129.	127.	10905.	7.	1763.	48.	6.0	6.2	
0015	6177.	0.	0.	0.	0.	0.	0.	1.	1.	1.	1.	1.0	1.0	
0016	5658.	0.	0.	0.	0.	0.	0.	1.	1.	1.	1.	1.0	1.0	
0017	5872.	403.	1273.	2086.	16204.	85.	80.	7376.	32.	1858.	273.	6.0	5.6	
0018	9294.	582.	838.	3663.	19303.	94.	92.	7982.	1.	2368.	295.	5.5	3.6	
0019	8536.	352.	2074.	2492.	15600.	95.	82.	7646.	1.	2350.	1063.	5.0	5.2	
0020	7525.	467.	1251.	2933.	17606.	85.	79.	7608.	6.	2376.	657.	4.5	5.2	
0021	13753.	289.	2993.	4438.	15003.	88.	79.	6761.	8.	4000.	2233.	4.5	5.1	
0022	9471.	295.	1912.	2821.	14101.	88.	80.	6330.	4.	2796.	1518.	4.0	5.8	
0023001	4416.	122.	808.	1239.	13905.	89.	73.	5750.	2.	1235.	934.	3.5	5.4	
0023002	2134.	0.	0.	0.	0.	0.	0.	1.	1.	1.	1.	1.0	1.0	
0024	5497.	179.	1094.	1491.	14200.	83.	77.	6003.	47.	1435.	1164.	3.5	5.3	
0025	9210.	295.	1541.	2940.	15994.	85.	78.	6033.	11.	2847.	1990.	3.5	4.5	
0026	2732.	0.	0.	0.	0.	0.	0.	1.	1.	1.	1.	1.0	1.0	
0027	11556.	179.	1905.	5070.	15398.	90.	87.	6161.	12.	4052.	661.	3.5	3.0	
0028	7087.	122.	897.	3168.	13602.	80.	74.	4964.	6.	3112.	893.	3.5	2.9	
0029	5431.	122.	1157.	1959.	13306.	75.	72.	4905.	15.	1874.	1749.	3.0	3.4	
0030	4532.	64.	302.	1728.	15398.	68.	64.	3866.	29.	1706.	1412.	3.0	2.6	
0031	4163.	64.	734.	1256.	12695.	75.	65.	4555.	1.	1187.	1208.	3.0	4.8	
0032	6608.	179.	1217.	1779.	13794.	79.	72.	4959.	20.	1725.	1696.	3.0	5.8	
0033	9490.	179.	1316.	2579.	13698.	73.	66.	5276.	8.	2571.	2397.	2.0	5.5	
0034	6864.	352.	912.	1686.	12695.	68.	60.	3944.	45.	1667.	1607.	2.5	4.2	
0035	2628.	186.	410.	838.	11499.	81.	68.	4346.	25.	754.	766.	2.5	4.5	
0036	5477.	122.	519.	2738.	12100.	75.	71.	4429.	20.	2657.	2099.	2.5	2.9	
0037	6304.	128.	115.	3422.	12296.	76.	74.	4666.	6.	3338.	1402.	2.5	2.5	
0038	5172.	128.	376.	2468.	14003.	85.	79.	5136.	6.	2424.	977.	3.0	3.1	
0039	5324.	124.	164.	2893.	13200.	89.	86.	6229.	1.	2633.	180.	3.0	3.2	
0040	7601.	186.	408.	3812.	16399.	87.	81.	6279.	9.	3652.	933.	3.0	3.2	
0041	3430.	0.	0.	0.	0.	0.	0.	1.	1.	1.	1.	1.0	1.0	
0042	9018.	243.	641.	4020.	14501.	74.	69.	4537.	73.	3944.	1867.	2.5	2.7	
0043	4532.	58.	441.	2137.	11004.	69.	65.	4822.	9.	2137.	1677.	2.5	2.8	
0044	3733.	58.	710.	1246.	12594.	70.	62.	3741.	48.	1230.	1168.	2.0	3.9	
0045	2450.	64.	392.	761.	12494.	73.	60.	3928.	24.	753.	720.	2.0	4.4	
0046	6799.	115.	466.	1644.	11103.	85.	66.	3874.	133.	1633.	1588.	1.5	4.6	
0047	6400.	109.	654.	1865.	11499.	70.	62.	3540.	75.	1826.	1555.	1.0	3.4	

Figure 3.1-1. List of Census Tract Attributes for the Washington, D.C. SMSA.

CENSUS TRACT ATTRIBUTES -- INPUT

WASHINGTON, D.C.

CENSUS TRACT NUMBER	TOTAL POPULATION	AREA IN SQUARE MILES	SINGLE FAMILY HOUSING	ALL HOUSING UNITS	PROPERTY VALUE	MEDIAN GROSS RENT	MEDIAN CONTRACT RENT	MEDIAN FAMILY INCOME	DILAPIDATED HOUSING UNITS	HOUSING OVER 10 YEARS OLD	NONWHITE OCCUPIED HOUSING DISTRICT	MEDIAN BUSINESS ROOMS IN HOUSING
0048	8485	186	1171	2359	12100	69	60	3200	340	2292	2213	1.5
0049	9000	115	926	2954	12296	66	58	3474	102	2925	2657	1.5
0050	8234	115	442	4064	14003	65	60	3467	26	3855	2485	2.0
0051	2451	0	0	0	0	0	0	1	1	1	1	1.0
0052001	6033	115	341	3109	13200	74	71	4163	1	3100	1232	2.0
0052002	1291	0	0	0	0	0	0	1	1	1	1	1.0
0053001	5896	54	871	3839	11696	76	71	5187	23	3429	663	2.5
0053002	1022	0	0	0	0	0	0	1	1	1	1	1.0
0054001	2624	0	0	0	0	0	0	1	1	1	1	1.0
0054002	831	0	0	0	0	0	0	1	1	1	1	1.0
0055	6180	237	700	3594	19594	74	68	4803	96	3255	683	2.5
0056	3797	160	472	2385	21540	101	99	7856	47	1043	221	3.0
0057001	5378	173	218	3338	22994	79	77	7895	88	3087	94	2.5
0057002	1404	0	0	0	0	0	0	1	1	1	1	1.0
0059	1449	0	0	0	0	0	0	1	1	1	1	1.0
0059	3870	0	0	0	0	0	0	1	1	1	1	1.0
0059	1699	0	0	0	0	0	0	1	1	1	1	1.0
0061	60	0	0	0	0	0	0	1	1	1	1	1.0
0062	99	0	0	0	0	0	0	1	1	1	1	1.0
0063	2360	0	0	0	0	0	0	1	1	1	1	1.0
0064	3262	173	452	1004	7303	64	54	2913	35	793	929	1.5
0065	4732	179	622	2055	14898	81	72	5791	176	1792	591	0.5
0066	3005	58	417	1342	17098	69	64	5388	3	1277	201	0.1
0067	6850	122	1043	2026	12900	78	65	4784	85	1984	1128	0.5
0069	10198	339	1196	2251	12900	76	64	5115	31	2135	1651	1.5
0069	4895	122	848	1261	11596	83	64	4460	77	1248	874	1.0
0070	5973	115	885	1651	11896	71	62	4717	126	1561	974	0.5
0071	4028	115	694	1126	11499	85	67	4732	72	948	636	1.0
0072	5552	282	556	1415	9792	61	55	2992	81	1259	795	1.0
0073001	4813	1453	730	735	13200	57	57	5250	1	673	78	3.5
0073002	5545	0	0	0	0	0	0	1	1	1	1	1.0
0073003	4483	283	383	1662	12900	79	77	6136	12	1255	42	3.0
0073004	5261	384	302	1687	13095	91	89	5245	71	922	159	3.0
0073005	9045	263	706	2530	12900	85	84	5100	1	1199	434	4.0
0073006	6648	173	248	2411	12296	87	86	6387	1	1682	48	4.0
0073007	6374	410	512	2387	13095	80	79	6477	1	2122	31	4.5
0073008	1044	0	0	0	0	0	0	1	1	1	1	1.0
0074001	6393	358	584	1199	11696	73	64	3429	10	874	1140	1.5
0074002	5132	289	796	1720	12296	81	73	5240	3	1105	1304	2.0
0074003	12542	288	482	3572	12394	81	78	5213	3	1119	3470	3.0
0075	9255	275	1123	3087	11656	91	74	5580	84	2373	722	2.5
0076001	5931	237	998	2219	12797	76	65	6464	43	2039	21	2.0
0076002	6508	697	969	2502	15804	93	78	7178	2	2065	17	2.5
0076003	5340	174	721	2260	19693	87	84	7959	1	2120	6	3.0
0077001	6217	634	471	2419	12797	71	69	5196	5	2156	339	2.0
0077002	6235	1862	1477	1914	14501	84	77	7990	1	1498	325	3.0
0077003	6419	582	352	2018	12695	77	74	5229	1	1486	850	4.0
0077004	11396	403	1723	3178	13306	78	76	5687	8	1912	2861	3.5

Figure 3.1-1. List of Census Tract Attributes for the Washington, D. C. SMSA (Cont'd)

CENSUS TRACT ATTRIBUTES -- INPUT														
WASHINGTON, D.C.														
CENSUS TRACT NUMBER	TOTAL POPULATION	AREA IN SQUARE MILES	SINGLE FAMILY HOUSING	ALL HOUSING UNITS	PROPERTY VALUE	MEDIAN GROSS RENT	MEDIAN CONTRACT RENT	MEDIAN FAMILY INCOME	HOUSING OVER 10 YEARS OLD	DILAPIDATED UNITS	NONWHITE OCCUPIED HOUSING DISTRICT	MEDIAN DISTANCE TO BUSINESS	MEDIAN DISTANCE TO HOUSING	
0077005	6336	237	1149	1466	13004	79	66	5151	15	15	978	1434	4.0	5.1
0078001	9111	871	339	1858	15199	75	70	3936	6	6	1284	1806	3.0	4.7
0078002	6654	525	1362	1908	12594	79	66	6595	3	3	1671	1786	2.5	5.1
0079003	6027	295	820	1730	12296	79	64	4569	26	26	1373	1703	3.5	3.8
0079004	4736	179	556	1107	14003	66	56	4537	10	10	971	1087	4.0	5.9
0078005	8283	295	1327	2338	10797	85	72	5345	50	50	1722	2296	4.0	4.1
0078006	10057	474	1584	2324	11897	82	66	5320	11	11	1211	2235	4.5	4.5
0079	9557	410	1360	2785	13306	78	64	4717	86	86	2703	2649	2.0	4.2
0080	12185	166	1679	3059	12494	78	63	4905	34	34	1552	2615	1.0	5.2
0081	5597	115	727	1588	12900	73	65	4760	34	34	1552	2615	1.0	5.2
0082	4218	179	592	2010	16498	73	67	6051	27	27	1945	250	0.1	3.2
0083	9897	179	1772	2647	12100	77	67	4573	148	148	2594	1794	0.5	4.5
0084	7583	115	1199	2008	12100	77	66	4727	27	27	1945	1581	1.0	4.2
0085	7073	122	1174	1669	12296	80	65	4694	21	21	1666	1512	1.0	5.5
0086	3752	243	683	898	11696	75	60	3519	246	246	832	782	1.0	3.9
0087	7201	237	1001	1935	12797	84	74	5172	12	12	1845	1575	1.5	5.3
0083001	7495	461	401	2197	12296	77	61	4578	40	40	1895	2080	1.5	3.4
0084002	7631	115	1234	2141	12200	78	63	4994	8	8	2039	1891	1.5	4.3
0085	10332	1805	926	2453	12594	75	66	4944	8	8	3359	3374	2.0	3.6
0090	2387	244	494	513	13698	1	1	6621	2	2	490	219	3.5	6.0
0091	9711	2279	1494	2963	13200	82	75	6614	13	13	2746	1256	3.0	5.7
0092	8055	346	1079	2253	13004	78	70	6342	24	24	2057	1014	2.5	4.7
0093	7855	510	1625	2387	15003	90	83	7052	7	7	1903	1716	3.0	5.7
0094	6015	723	1542	1727	13399	94	84	8039	4	4	1558	1061	3.5	6.3
0095	3930	461	225	1289	14500	86	82	6701	1	1	518	154	4.0	3.3
0096	7832	467	1646	2231	14300	79	68	7692	14	14	1808	878	4.0	5.7
0097	4596	510	1179	1182	12292	1	1	9721	1	1	815	535	4.0	6.2
0098	10320	640	2359	3100	16399	104	98	8193	2	2	766	862	5.0	5.7
0099	7451	0	0	0	0	0	0	0	1	1	1	1	1.0	1.0
0100	2133	0	0	0	0	0	0	0	1	1	1	1	1.0	1.0
0101	4487	27182	1192	1270	17206	82	60	6285	64	64	796	65	31.5	5.7
0102	3137	34108	737	807	15306	64	45	5519	69	69	551	82	30.0	5.7
0103	2071	25167	557	557	11802	1	1	5049	13	13	427	95	30.0	5.8
0104	1920	0	0	0	0	0	0	0	1	1	1	1	1.0	1.0
0105	3526	23047	932	932	13200	1	1	5949	105	105	645	119	0.1	5.5
0106	4425	1671	809	1266	16597	89	81	6775	25	25	652	7	22.5	5.1
0107	4337	30251	1100	1140	14501	76	55	5547	84	84	686	198	22.5	5.0
0108	5846	1671	1193	1460	13602	91	75	6336	56	56	618	297	17.0	5.1
0109	6651	2797	1232	1924	17001	96	82	7519	28	28	754	84	17.5	5.1
0110	1535	1152	3143	3153	14400	141	107	8071	1	1	445	7	16.0	5.5
0111	8743	5241	2057	2345	17998	136	132	8805	14	14	292	15	13.5	5.0
0112	3063	11702	824	830	24909	1	1	7919	80	80	367	58	15.0	5.1
0113	5119	2127	1353	1462	19206	83	66	7646	99	99	860	308	21.0	5.9
0114	6748	29269	1806	1846	21290	85	59	8095	116	116	982	231	17.5	5.8
0115	3367	7371	2345	2352	28001	1	1	11743	26	26	510	65	14.5	5.8
0116	5791	704	767	1495	18602	111	110	8527	1	1	125	10	9.5	4.9
0117	7703	345	659	2904	15306	89	86	6438	44	44	2076	38	6.0	5.6
0118	1819	231	794	1235	16204	95	92	8250	14	14	913	70	6.5	5.6

Figure 3.1-1. List of Census Tract Attributes for the Washington, D.C. SMSA (Cont'd)

CENSUS TRACT ATTRIBUTES -- INPUT

WASHINGTON, D.C.

CENSUS TRACT NUMBER	TOTAL POPULATION	AREA IN SQUARE MILES	SINGLE FAMILY HOUSING	ALL HOUSING UNITS	HOUSING PROPERTY VALUE	MEDIAN GROSS RENT	MEDIAN CONTRACT RENT	MEDIAN FAMILY INCOME	MEDIAN DILAPIDATED HOUSING UNITS	HOUSING OVER 10 YEARS OLD	MINUTE DISTANCE TO OCCUPIED BUSINESS PLACES IN DISTRICT
WDC0019	3328	0.0	0	0	0	0	0	0	1	1	1.0
WDC0020	4761	1.1	641	1407	17206	97	93	7793	1	481	5.0
WDC0021	6621	6.7	1599	1949	19990	130	108	10322	10000	917	7.5
WDC0022	4451	2.1	1327	1419	19303	1	1	10386	1	1100	2.0
WDC0023	6352	3.9	1725	2373	18602	103	96	8160	1	1075	6.2
WDC0024	6248	4.7	1572	2143	18602	127	121	9500	3	1447	5.2
WDC0025	1638	0.0	0	0	0	0	0	1	1	1	1.0
WDC0026	5932	0.0	0	0	0	0	0	1	1	1	1.0
WDC0027	4453	4.0	1033	1430	22100	137	132	11004	42	369	1.0
WDC0028	3453	3.0	996	996	19303	1	1	10107	6	732	5.8
WDC0029	5030	5.1	1465	1504	26213	1	1	12607	1	945	6.3
WDC0030	3655	3.8	1002	1014	18996	1	1	10158	1	657	6.7
WDC0031	5141	9.7	1325	1325	17801	1	1	9054	1	562	6.3
WDC0032	12003	0.0	0	0	0	0	0	1	1	1	1.0
WDC0033	4747	1.9	2160	2160	17206	1	1	8300	1	8	1.0
WDC0034	16314	1.7	3905	3905	17001	148	116	9136	1	267	5.3
WDC0035	8955	1.6	2242	2242	13200	113	87	7731	48	732	5.9
WDC0036	7927	5.9	1974	2061	17103	1	1	5596	6	787	5.3
WDC0037	8796	4.0	2217	2217	15199	1	1	8544	2	889	5.4
WDC0038	1220	3.9	253	355	14104	1	1	7739	1	122	5.7
WDC0039	8275	1.2	2026	2026	18106	109	109	9256	15	792	5.1
WDC0040	5826	5.7	1268	1732	18106	1	1	902	1	902	9.5
WDC0041	6232	1.0	1232	1232	31513	1	1	10557	16	502	5.5
WDC0042	2175	2.9	520	597	18996	1	1	9027	1	405	7.1
WDC0043	6498	3.6	1391	1391	18807	1	1	397	1	397	6.1
WDC0044	9711	1.0	1557	1830	27500	169	145	10952	1	327	10.0
WDC0045	4564	6.0	1329	2460	22607	1	1	10896	1	559	6.6
WDC0046	4564	6.0	1329	2460	22607	1	1	12113	1	871	5.5
WDC0047	4416	3.2	1299	1323	28210	1	1	1357	2	1026	6.4
WDC0048	6782	3.2	551	2916	21795	105	101	7966	19	1741	7.2
WDC0049	1103	0.0	0	0	0	0	0	1	1	1	1.0
WDC0050	4320	4.8	1302	1318	19032	154	127	9927	1	1	1.0
WDC0051	4895	6.0	1319	1437	29752	197	150	13685	3	1111	6.0
WDC0052	4008	4.0	1138	1138	31288	1	1	14429	1	692	7.0
WDC0053	2405	0.0	0	0	0	0	0	1	1	1	1.0
WDC0054	3456	4.8	994	994	26213	1	1	13521	1	965	1.2
WDC0055	4176	1.1	1128	1154	33300	0	0	1275	1	638	7.3
WDC0056	4198	3.2	1317	1366	23110	1	1	11778	3	1128	6.3
WDC0057	7523	0.0	0	0	0	0	0	1	1	1	1.0
WDC0058	5045	1.7	1306	1533	18504	105	94	9760	42	860	5.7
WDC0059	9837	1.4	2700	2700	31508	1	1	14115	5	519	7.2
WDC0060	4747	0.0	0	0	0	0	0	1	1	1	1.0
WDC0061	8532	1.0	1633	2902	14603	105	91	6106	64	1417	1.3
WDC0062	2700	4.9	699	721	16101	1	1	7016	73	368	6.2
WDC0063	679	0.0	0	0	0	0	0	1	1	1	1.0
WDC0064	5967	2.4	1435	1460	15199	76	57	7339	80	805	1.0
WDC0065	3031	0.0	0	0	0	0	0	1	1	1	1.0
WDC0066	3304	2.1	735	798	13200	62	45	5298	54	558	5.1

Figure 3.1-1. List of Census Tract Attributes for the Washington, D.C. SMSA (Cont'd)

WASHINGTON, D.C. CENSUS TRACT ATTRIBUTES -- INPUT

CENSUS TRACT NUMBER	TOTAL POPULATION	AREA IN SQUARE MILES	SINGLE FAMILY HOUSING	ALL HOUSING UNITS	MEDIAN PROPERTY VALUE	MEDIAN GROSS RENT	MEDIAN CONTRACT RENT	FAMILY INCOME	HOUSING OVER 10 YEARS OLD	NONWHITE HOUSING	DISTANCE TO BUSINESS DISTRICT	MEDIAN HOUSING
PGC0007	2857	21021	636	673	12797	1	0	5750	53	392	203	16.0
PGC0009	1910	0	0	0	0	0	0	1	1	1	1	1.0
PGC0009	1618	0	0	0	0	0	0	1	1	1	1	1.0
PGC0010	4708	37283	1021	1090	12296	60	48	6708	116	644	327	18.0
PGC0011	3968	0	0	0	0	0	0	1	1	1	1	1.0
PGC0012	8848	13647	2319	2373	15994	100	78	7801	128	917	143	13.0
PGC0013	7303	53546	1937	1984	14400	90	66	6714	172	932	209	13.0
PGC0014	9710	10544	2543	2579	16204	118	86	7943	60	536	127	8.0
PGC0015	3523	256	897	905	16399	1	1	8964	1	297	8	5.0
PGC0016	4018	0	0	0	0	0	0	1	1	1	1	1.0
PGC0017	6254	3454	1706	1715	17606	1	1	8519	32	470	19	2.0
PGC0018	13891	1280	3252	3816	16899	103	84	8201	3	659	15	4.5
PGC0019	9386	4892	2217	2558	18398	101	93	8071	50	1196	44	5.5
PGC0020	4142	614	305	1488	15600	85	82	5687	10	1330	8	6.0
PGC0021	4167	1985	1110	1160	18106	1	1	7216	12	393	12	7.0
PGC0022	5245	2687	1289	1299	14603	1	1	6991	55	424	142	8.0
PGC0023	7525	544	1139	2084	17001	88	88	7662	1	655	11	6.5
PGC0024	4974	1856	1162	1360	14501	92	88	7662	42	655	120	4.0
PGC0025	5009	557	968	1596	14200	89	87	7087	16	1114	13	4.0
PGC0026	3258	237	666	891	10405	93	84	5997	19	716	4	4.0
PGC0027	4528	295	1103	1210	11204	92	69	6755	88	937	22	4.5
PGC0028	4798	3617	1157	1198	13400	1	1	6628	39	639	63	6.5
PGC0029	5367	448	880	1503	12695	83	82	6155	18	592	112	5.5
PGC0030	4510	410	954	1030	10700	75	53	4465	175	763	984	5.5
PGC0031	4298	525	721	1062	11802	70	67	5378	31	676	1021	5.0
PGC0032	2535	0	0	0	0	0	0	1	1	1	1	1.0
PGC0033	3248	614	789	913	11603	103	103	6967	12	171	7	6.5
PGC0034	5405	604	609	1309	11499	1	1	6802	5	16	5	5.1
PGC0035	2703	15730	579	602	9302	1	1	5591	125	451	345	13.5
PGC0036	1244	7490	3402	3415	16107	1	1	8226	105	946	317	13.0
PGC0037	3271	320	796	796	13306	1	1	7966	1	610	8	7.5
PGC0038	5569	640	1384	1410	15093	1	1	7856	1	232	4	7.5
PGC0039	1623	295	847	993	14501	93	91	7856	5	548	5	5.1
PGC0040	3103	640	647	903	14101	91	89	7639	25	754	31	5.5
PGC0041	3816	672	962	962	14603	1	1	7586	4	374	7	6.5
PGC0042	4910	416	1310	1319	18695	1	1	11004	23	870	30	5.5
PGC0043	3862	1280	564	1157	14300	88	76	7087	11	617	81	5.0
PGC0044	2873	640	710	901	11305	83	73	6555	9	853	2	4.5
PGC0045	864	0	0	0	0	0	0	1	1	1	1	1.0
PGC0046	1642	237	650	1131	11802	84	85	6940	15	1009	6	5.0
PGC0047	6610	256	1025	1485	11897	81	72	7037	19	1400	9	4.5
PGC0048	5223	0	0	0	0	0	0	1	1	1	1	1.0
PGC0049	2387	243	527	540	17998	1	1	9624	1	428	2	4.5
PGC0050	5620	480	686	1633	17606	83	82	6953	1	1092	11	5.5
PGC0051	4652	320	574	1525	13095	85	85	6850	1	393	12	5.5
PGC0052	5941	416	1189	2010	15693	110	107	8617	4	867	12	5.5
PGC0053	2515	250	582	740	15926	1	1	7361	10	602	32	6.5
PGC0054	2738	224	626	869	19206	96	92	8630	1	487	6	7.0

Figure 3.1-1. List of Census Tract Attributes for the Washington, D.C. SMSA (Cont'd)

CENSUS TRACT ATTRIBUTES --- INPUT													
WASHINGTON, D.C.													
CENSUS TRACT NUMBER	TOTAL POPULATION	AREA IN SQUARE MILES	SINGLE FAMILY HOUSING	ALL HOUSING UNITS	MEDIAN PROPERTY VALUE	MEDIAN GROSS RENT	MEDIAN CONTRACT RENT	MEDIAN FAMILY INCOME	MEDIAN DILAPIDATED HOUSING UNITS	HOUSING OVER 10 YEARS OLD	NONWHITE OCCUPIED	DISTRICT HOUSING	MEDIAN DISTANCE TO BUSINESS ROOMS IN HOUSING
PGC0055	4209.	295.	625.	1312.	15693.	86.	83.	7548.	1.	303.	11.	6.5	4.3
PGC0056	6270.	0.	0.	0.	0.	0.	0.	1.	1.	1.	1.	1.0	1.0
PGC0057	5240.	320.	905.	1562.	15899.	114.	100.	8259.	1.	96.	19.	7.0	4.6
PGC0058	7237.	614.	1708.	1918.	16697.	118.	115.	8717.	1.	466.	14.	6.5	5.7
PGC0059	7332.	1537.	988.	2512.	19303.	108.	103.	8893.	1.	133.	24.	7.0	4.2
PGC0060	4624.	224.	907.	1404.	13602.	99.	99.	7817.	1.	739.	5.	5.5	4.9
PGC0061	4126.	256.	951.	1251.	15003.	85.	83.	8308.	1.	1177.	4.	5.5	5.4
PGC0062	4222.	352.	858.	1319.	14706.	89.	84.	7631.	30.	1090.	44.	5.0	5.3
PGC0063	2993.	410.	598.	831.	12296.	83.	76.	6809.	26.	767.	34.	5.5	5.0
PGC0064	3053.	352.	864.	885.	23388.	1.	1.	12357.	1.	611.	2.	6.5	4.6
PGC0065	4474.	1024.	1072.	1314.	13602.	82.	75.	7237.	14.	1022.	6.	6.5	5.4
PGC0066	8333.	1312.	1664.	2233.	13095.	98.	94.	7864.	8.	1229.	12.	7.5	5.1
PGC0067	7716.	6914.	1824.	2211.	4999.	77.	73.	6823.	2.	1920.	7.	10.5	4.4
PGC0068	2419.	416.	651.	657.	15693.	1.	1.	8193.	4.	186.	1.	9.0	5.3
PGC0069	4142.	307.	1042.	1047.	13698.	1.	1.	8136.	8.	241.	4.	10.0	5.3
PGC0070	4722.	992.	1141.	1256.	13602.	89.	67.	6926.	65.	855.	146.	9.0	5.4
PGC0071	5182.	819.	852.	1513.	22404.	91.	90.	9711.	9.	1049.	25.	7.5	5.5
PGC0072	3741.	0.	0.	0.	0.	0.	0.	1.	1.	1.	1.	1.0	1.0
PGC0073	389.	6281.	756.	756.	13.	730.	10.	649.	10.	756.	3.	3.5	6.0
PGC0074	8409.	18626.	2215.	2239.	17001.	76.	61.	7990.	34.	768.	137.	16.5	5.5
ARL0001	5415.	557.	1507.	1512.	20292.	167.	135.	10446.	2.	497.	3.	8.0	5.4
ARL0002	6569.	845.	1858.	1889.	22994.	182.	147.	11464.	1.	759.	6.	7.5	6.2
ARL0003	6045.	0.	0.	0.	0.	0.	0.	1.	1.	1.	1.	1.0	1.0
ARL0004	3093.	0.	0.	0.	0.	0.	0.	1.	1.	1.	1.	1.0	1.0
ARL0005	3917.	467.	1674.	1205.	21504.	154.	125.	11339.	10.	804.	7.	6.0	5.3
ARL0006	2779.	237.	724.	878.	16301.	110.	88.	7778.	6.	756.	1.	5.5	5.6
ARL0007	5177.	346.	1229.	1821.	18695.	95.	91.	8920.	9.	1344.	72.	6.0	5.4
ARL0008	1608.	122.	340.	394.	13602.	1.	1.	4750.	86.	288.	319.	6.5	5.1
ARL0009	5198.	378.	1111.	1666.	21504.	90.	79.	9760.	2.	1331.	34.	7.0	5.7
ARL0010	3656.	263.	906.	1176.	17292.	105.	95.	9154.	3.	1043.	3.	7.5	5.5
ARL0011	4939.	699.	1361.	1389.	20098.	171.	141.	10594.	6.	526.	3.	9.0	6.2
ARL0012	3533.	352.	860.	977.	19594.	144.	132.	10087.	1.	442.	4.	7.0	6.1
ARL0013	7094.	576.	1839.	2020.	17396.	158.	116.	9136.	44.	1629.	2.	6.2	6.0
ARL0014	3456.	314.	604.	1232.	15693.	87.	80.	6919.	28.	1091.	12.	6.0	4.6
ARL0015	5009.	443.	1100.	2226.	19399.	107.	102.	8570.	10.	1278.	7.	5.0	5.4
ARL0016	5319.	410.	413.	2538.	14300.	91.	89.	8119.	2.	1797.	29.	4.0	3.5
ARL0017	7369.	256.	239.	5089.	17001.	97.	96.	7295.	7.	1356.	29.	4.0	2.9
ARL0018	7187.	410.	975.	2902.	15899.	92.	90.	7631.	4.	2126.	33.	4.5	3.9
ARL0019	2925.	263.	792.	998.	18695.	89.	79.	9219.	2.	904.	1.	5.5	5.0
ARL0020	6470.	224.	298.	2867.	17908.	97.	88.	7435.	1.	2644.	14.	6.0	3.4
ARL0021	1910.	237.	536.	542.	18398.	1.	1.	9818.	1.	322.	1.	6.5	5.1
ARL0022	3805.	173.	393.	1451.	12394.	107.	103.	6425.	2.	949.	11.	6.5	3.0
ARL0023	4437.	461.	998.	1299.	17908.	113.	98.	9036.	5.	939.	2.	5.5	5.6
ARL0024	3968.	173.	617.	1411.	16399.	105.	97.	7115.	7.	987.	83.	5.0	4.6
ARL0025	3031.	237.	589.	1192.	16798.	89.	88.	8033.	17.	1126.	56.	5.0	4.5
ARL0026	2987.	173.	575.	1026.	14200.	105.	94.	7531.	4.	476.	3.	5.5	4.6
ARL0027	3594.	115.	126.	1504.	17908.	92.	91.	7624.	1.	1056.	18.	6.0	3.9
ARL0028	4376.	493.	909.	1477.	15506.	117.	112.	7919.	4.	690.	3.	6.5	4.5

Figure 3.1-1. List of Census Tract Attributes for the Washington, D.C. SMSA (Cont'd)

CENSUS TRACT ATTRIBUTES -- INPUT													
WASHINGTON, D.C.													
CENSUS TRACT NUMBER	TOTAL POPULATION	AREA IN SQUARE MILES	SINGLE FAMILY HOUSING	ALL HOUSING UNITS	MEDIAN PROPERTY VALUE	MEDIAN GROSS RENT	MEDIAN CONTRACT RENT	MEDIAN FAMILY INCOME	MEDIAN DILAPIDATED HOUSING UNITS	HOUSING OVER 10 YEARS OLD	NONWHITE DISTRICT	MEDIAN BUSINESS BOOMS IN	MEDIAN DISTRICT HOUSING
A1L0029	5994	0.	0.	0.	0.	0.	0.	1.	1.	1.	1.	1.0	1.0
A1L0030	4198	0.	0.	0.	0.	0.	0.	1.	1.	1.	1.	1.0	1.0
A1L0031	4523	288.	983.	1001.	11696.	91.	74.	5335.	29.	854.	970.	5.5	5.1
A1L0032	4942	461.	767.	2438.	15003.	114.	111.	6831.	1.	1101.	4.	5.0	3.7
A1L0033	913.	59.	180.	233.	13794.	1.	1.	4670.	3.	149.	230.	4.0	5.2
A1L0034	6976	0.	0.	0.	0.	0.	0.	1.	1.	1.	1.	1.0	1.0
A1L0035	1210	0.	0.	0.	0.	0.	0.	1.	1.	1.	1.	1.0	1.0
A1L0036	3087	179.	762.	994.	16597.	114.	102.	8485.	3.	860.	1.	4.0	5.6
A1L0037	2719	0.	0.	0.	0.	0.	0.	1.	1.	1.	1.	1.0	1.0
A1L0038	3913	237.	296.	1751.	13200.	94.	91.	7935.	1.	943.	7.	4.5	3.3
FAX0001	3913	283.	907.	992.	11696.	110.	88.	6721.	7.	519.	6.	7.0	4.4
FAX0002	3616	806.	1107.	1154.	22703.	1.	1.	9471.	15.	384.	69.	7.5	6.0
FAX0003	4101	1095.	316.	1310.	26108.	108.	108.	7354.	2.	1000.	3.	7.5	5.2
FAX0004	7998	1612.	2140.	2233.	15003.	118.	97.	7473.	42.	419.	92.	9.0	5.1
FAX0005	9319	4205.	2581.	2592.	24005.	96.	61.	11070.	163.	661.	237.	10.5	5.3
FAX0006	5991	368.	1584.	1746.	22093.	88.	81.	7406.	37.	532.	51.	12.0	5.5
FAX0007	7784	0.	0.	0.	0.	0.	0.	1.	1.	1.	1.	1.0	1.0
FAX0008	1108	9792.	348.	359.	9997.	1.	1.	6843.	21.	211.	13.	18.0	4.6
FAX0009	5822	3627.	2235.	2308.	17103.	152.	132.	8630.	37.	314.	16.	9.0	5.8
FAX0010	7976	6852.	2099.	2107.	17801.	121.	92.	8022.	61.	495.	29.	10.5	5.4
FAX0011	6743	1152.	1583.	1781.	15506.	102.	87.	7593.	2.	571.	3.	7.5	5.1
FAX0012	6267	5532.	1699.	1878.	15994.	99.	87.	6522.	63.	781.	6.	10.5	5.0
FAX0013	3920	0.	0.	0.	0.	0.	0.	1.	1.	1.	1.	1.0	1.0
FAX0014	6789	27236.	863.	969.	11305.	79.	65.	6033.	64.	593.	31.	18.0	4.4
FAX0015	2150	0.	0.	0.	0.	0.	0.	1.	1.	1.	1.	1.0	1.0
FAX0016	3631	582.	654.	1205.	22697.	95.	93.	8485.	19.	223.	5.	7.5	4.5
FAX0017	7406	1671.	1159.	2260.	23999.	107.	102.	9858.	9.	1184.	20.	7.5	5.2
FAX0018	4537	1095.	1135.	1145.	31996.	1.	1.	13200.	1.	42.	6.	8.0	7.4
FAX0019	6735	2650.	1748.	1783.	20292.	150.	113.	9386.	43.	474.	231.	8.5	5.3
FAX0020	13643	4206.	3548.	3555.	18891.	169.	135.	9481.	44.	601.	22.	9.5	5.3
FAX0021	3000	1843.	2224.	2295.	19990.	166.	133.	9967.	7.	15.	4.	11.5	5.0
FAX0022	2705	10481.	786.	786.	18902.	1.	1.	7895.	20.	247.	6.	14.5	5.7
FAX0023	6192	1152.	1055.	1621.	16107.	117.	106.	7867.	10.	728.	54.	11.5	5.3
FAX0024	6515	576.	1541.	1735.	15506.	136.	107.	8127.	22.	1360.	111.	7.5	5.7
FAX0025	3285	2650.	821.	821.	18398.	1.	1.	8831.	23.	273.	59.	12.0	5.8
FAX0026	4020	1325.	1049.	1050.	19791.	1.	1.	10770.	1.	29.	3.	10.5	6.7
FAX0027	4939	461.	1286.	1286.	15501.	1.	1.	8342.	1.	309.	3.	9.0	5.0
FAX0028	4425	1095.	1170.	1170.	21895.	1.	1.	10721.	2.	204.	1.	9.0	5.1
FAX0029	5374	805.	1422.	1422.	21590.	1.	1.	10551.	1.	144.	1.	9.0	6.3
FAX0030	5659	14176.	1339.	1501.	19791.	125.	114.	8604.	43.	423.	38.	15.0	5.4
FAX0031	5514	2650.	1390.	1405.	19594.	161.	125.	9500.	68.	682.	64.	3.0	5.0
FAX0032	5049	4206.	134.	1373.	17001.	1.	1.	7662.	26.	787.	84.	3.0	5.7
FAX0033	11441	2650.	2845.	2925.	18197.	144.	113.	8375.	39.	554.	112.	2.0	5.8
FAX0034	3460	4721.	1018.	1029.	2292.	1.	1.	8699.	28.	235.	12.	2.5	5.4
FAX0035	13589	3110.	3433.	3623.	18306.	142.	112.	8630.	27.	663.	85.	2.5	5.7
FAX0036	4101	11525.	1162.	1192.	20806.	1.	1.	8417.	42.	572.	61.	3.0	5.7
FAX0037	5210	1722.	1492.	1512.	19497.	1.	1.	9538.	7.	537.	4.	3.0	5.9
FAX0038	7435	1727.	1727.	1730.	13602.	1.	1.	7252.	8.	198.	3.	3.0	5.1

Figure 3.1-1. List of Census Tract Attributes for the Washington, D.C. SMSA (Cont'd)

WASHINGTON, D.C.													
CENSUS TRACT ATTRIBUTES -- INPUT													
CENSUS TRACT NUMBER	TOTAL POPULATION	AREA IN SQUARE MILES	SINGLE FAMILY HOUSING	ALL HOUSING UNITS	PROPERTY VALUE	MEDIAN GROSS RENT	MEDIAN CONTRACT RENT	MEDIAN FAMILY INCOME	DILAPIDATED HOUSING UNITS	HOUSING OVER 10 YEARS OLD	NONWHITE OCCUPIED	DISTANCE TO BUSINESS DISTRICT	MEDIAN ROOMS IN HOUSING
FAX0039	8527	2131	2191	2200	23600	195	150	10732	10	338	27	3.5	5.8
FAX0040	5902	6281	1735	1741	30792	1	1	12357	10	525	42	3.5	7.0
FAX0041	4638	25344	1400	1408	24197	1	1	9109	85	792	104	3.5	5.9
FAX0042	4194	31675	1109	1148	11696	1	1	6355	134	715	115	2.5	5.3
FAX0043	2359	23047	649	666	15003	1	1	6905	45	415	21	2.5	5.1
FAX0044	3652	33400	981	1016	13306	1	1	5802	50	662	50	2.0	5.5
FAX0045	1961	2879	494	578	16204	1	1	7443	49	389	16	2.0	5.6
ALX0001	2719	1574	494	950	21807	101	95	8682	3	476	4	8.0	5.1
ALX0002	2305	960	443	728	24392	135	118	9200	4	73	11	7.0	4.4
ALX0003	3509	851	898	903	22404	162	117	9957	2	36	3	0.1	4.0
ALX0004	422	0	0	0	0	0	0	1	1	1	1	1.0	1.0
ALX0005	6248	0	0	0	0	0	0	1	1	1	1	1.0	1.0
ALX0006	3737	614	996	1002	15899	1	1	7832	2	88	7	8.0	5.3
ALX0007	2561	819	684	781	11396	85	84	5586	75	798	70	4.0	3.4
ALX0008	5438	935	1589	1835	22093	66	66	7237	12	1034	71	7.0	5.2
ALX0009	5351	621	1352	1471	23295	161	126	11441	2	884	20	6.0	6.4
ALX0010	4155	0	0	0	0	0	0	1	1	1	1	1.0	1.0
ALX0011	6575	346	855	2463	23295	90	89	7887	6	1749	77	5.0	4.0
ALX0012	8502	442	1906	2558	12900	103	92	7201	2	1347	59	4.5	4.3
ALX0013	4944	352	1192	1512	12695	90	77	7281	63	1375	17	5.5	5.1
ALX0014	5070	289	1022	1691	14300	94	88	7317	5	1343	8	5.5	5.0
ALX0015	4496	384	1211	1401	16301	101	85	8358	3	1179	1	6.5	5.6
ALX0016	5481	256	1236	1362	11204	77	55	3889	63	1220	1007	6.0	5.2
ALX0017	992	582	132	465	23295	79	78	7631	6	444	9	4.5	3.6
ALX0018	6419	237	1050	2285	13494	84	80	5415	72	1924	530	6.0	4.1
ALX0019	3220	147	577	1181	16003	80	67	5603	147	1171	149	6.5	4.2
ALX0020	7879	295	1214	3252	16899	89	84	7023	203	2317	456	7.5	3.7
FC0001	2347	352	594	626	19306	1	1	9219	1	404	4	9.5	6.0
FC0002	5768	576	1452	1661	18106	110	96	7959	16	1	16	10.0	5.2
FC0003	2034	295	533	608	26108	1	1	11649	2	1	20	8.5	5.5

Figure 3.1-1. List of Census Tract Attributes for the Washington, D.C. SMSA (Cont'd)

CENSUS TRACT	OWN	RENT	CENSUS TRACT	OWN	RENT
0001			0028	370.92	2816.
0002			0029	551.15	1360.
0003	1034.64	1424.	0030	256.98	1416.
0004			0031	462.20	764.
0005			0032	873.93	870.
0006	1130.03	1083.	0033	1105.44	1436.
0007	796.32	3945.	0034	375.03	1244.
0008			0035	264.01	508.
0009			0036	297.97	2357.
0010	2061.11	3158.	0037	175.04	2815.
0011	1084.64	624.	0038	195.93	2107.
0012	858.34	1273.	0039	491.76	2304.
0013			0040	444.97	3223.
0014	1415.16	923.	0041		
0015			0042	361.04	3480.
0016			0043	286.86	1789.
0017	1130.03	916.	0044	222.96	947.
0018	802.72	2677.	0045	173.99	548.
0019	1925.61	534.	0046	427.09	1175.
0020	1143.67	1331.	0047	212.09	1591.
0021	2075.59	2262.	0048	320.86	1903.
0022	1578.14	1183.	0049	303.08	2526.
0023001	716.95	-498.	0050	229.06	3453.
0023002			0051		
0024	772.01	691.	0052001	206.03	2707.
0025	1191.54	1701.	0052002		
0026			0053001	240.03	3393.
0027	1068.49	3775.	0053002		

Figure 3.1-1. List of Census Tract Attributes for the Washington, D.C. SMSA (Cont'd)

CENSUS TRACT	ϕ_{WN}	RENT
0054001		
0054002		
0050055	229.93	3083.
0050056	366.87	1844.
0057001	95.97	3062.
0057002		
0058		
0059		
0060		
0061		
0062		
0063		
0064	90.00	862.
0065	457.14	1345.
0066	294.12	925.
0067	586.99	1309.
0068	878.31	1324.
0069	424.96	763.
0070	358.17	1194.
0071	297.03	688.
0072	78.96	1294.
0073001	66.02	649.
0073002		
0073003	280.90	1319.
0073004	194.03	1441.
0073005	280.06	2131.
0073006	224.08	2113.
0073007	399.02	1913.

CENSUS TRACT	ϕ_{WN}	RENT
0073008		
0074001	95.97	1057.
0074002	504.21	1116.
0074003	342.06	3175.
0075	555.15	2424.
0076001	738.78	1432.
0076002	897.85	1523.
0076003	714.08	1476.
0077001	397.02	1947.
0077002	1319.49	545.
0077003	303.08	1555.
0077004	1303.75	1756.
0077005	804.32	636.
0078001	326.03	1509.
0078002	1136.73	712.
0078003	532.89	1122.
0078004	412.82	676.
0078005	960.06	1342.
0078006	704.16	1534.
0079	990.29	1752.
0080	1142.53	1832.
0081	453.05	1079.
0082	384.91	1471.
0083	770.66	1741.
0084	618.03	1223.
0085	722.70	922.
0086	140.05	703.
0087	749.95	1113.

Figure 3.1-1. List of Census Tract attributes for the Washington, D.C. SMSA (Cont'd)

CENSUS TRACT	ØWN	RENT	CENSUS TRACT	ØWN	RENT
0088001	230.90	1940.	MOC0015	1974.36	142
0088002	739.18	1313.	MOC0016	711.94	766.
0089	512.86	2903.	MOC0017	750.69	1937.
0090	362.85	139.	MOC0018	717.66	469.
0091	1265.22	1625.	MOC0019		
0092	778.21	1380.	MOC0020	585.81	803.
0093	1214.39	1104.	MOC0021	1449.54	411.
0094	1391.31	308.	MOC0022	1241.41	153.
0095001	242.01	1005.	MOC0023	575.94	1525.
0095002	1376.09	834.	MOC0024	1334.03	659.
0095003	1034.64	81.	MOC0025		
0095004	2214.93	823.	MOC0026		
0096			MOC0027	831.00	351.
MOC0001			MOC0028	869.57	109.
MOC0002	864.37	333.	MOC0029	1355.49	114.
MOC0003	453.05	284.	MOC0030	915.93	63.
MOC0004	335.96	172.	MOC0031	1245.14	64.
MOC0005			MOC0032	2737.00	215.
MOC0006	555.02	281.	MOC0033	1960.59	83.
MOC0007	692.29	544.	MOC0034	3512.21	256.
MOC0008	758.24	315.	MOC0035	1855.67	299.
MOC0009	972.63	456.	MOC0036	1736.43	197.
MOC0010	994.26	819.	MOC0037	2006.21	172.
MOC0011	2777.00	296.	MOC0038	212.84	124.
MOC0012A	1840.83	422.	MOC0039	1559.33	154.
MOC0012B	575.94	198.	MOC0040	1134.53	558.
MOC0013	938.23	386.	MOC0041	1071.00	110.
MOC0014	1331.42	357.	MOC0042	444.97	133.

Figure 3.1-1. List of Census Tract Attributes for the Washington, D.C. SMSA (Cont'd)

CENSUS TRACT	ØWN	RENT	CENSUS TRACT	ØWN	RENT
MOC0043	1245.14	129.	PGC0011		
MOC0044	1390.00	345.	PGC0012	1759.88	413.
MOC0045	2192.00	210.	PGC0013	1426.53	417.
MOC0046	2159.13	141.	PGC0014	2115.40	287.
MOC0047	1157.48	169.	PGC0015	790.76	101.
MOC0048	1114.32	2515.	PGC0016		
MOC0049			PGC0017	1436.55	189.
MOC0050	1052.53	241.	PGC0018	2303.07	1315.
MOC0051	1125.52	272.	PGC0019	1796.70	750.
MOC0052	1026.59	78.	PGC0020	280.90	1140.
MOC0053			PGC0021	930.76	169.
MOC0054	832.71	104.	PGC0022	1046.28	202.
MOC0055	1040.00	92.	PGC0023	1065.29	951.
MOC0056	1151.00	165.	PGC0024	909.60	379.
MOC0057			PGC0025	860.06	688.
MOC0058	1124.39	350.	PGC0026	497.20	355.
MOC0059	2435.72	125.	PGC0027	810.73	363.
MOC0060			PGC0028	932.62	222.
PGC0001	929.83	1751.	PGC0029	679.26	715.
PGC0002	500.20	185.	PGC0030	671.15	314.
PGC0003			PGC0031	620.17	429.
PGC0004	1013.33	339.	PGC0032		
PGC0005			PGC0033	632.66	166.
PGC0006	386.84	348.	PGC0034	1157.48	65.
PGC0007	362.13	275.	PGC0035	345.59	222.
PGC0008			PGC0036	2217.79	188.
PGC0009			PGC0037	736.04	47.
PGC0010	704.16	300.	PGC0038	1235.91	79.

Figure 3.1-1. List of Census Tract Attributes for the Washington, D.C. SMSA (Cont'd)

CENSUS TRACT	<u>ØWN</u>	<u>RENT</u>	CENSUS TRACT	<u>ØWN</u>	<u>RENT</u>
PGC0039	737.30	225.	PGC0067	1768.70	389.
PGC0040	579.93	304.	PGC0068	581.14	32.
PGC0041	866.97	64.	PGC0069	953.37	65.
PGC0042	1202.31	83.	PGC0070	940.11	272.
PGC0043	465.91	663.	PGC0071	766.63	708.
PGC0044	589.93	281.	PGC0072		
PGC0045			PGC0073	706.27	30.
PGC0046	582.89	524.	PGC0074	1790.05	357.
PGC0047	833.60	558.	ARL0001	1235.21	245.
PGC0048			ARL0002	1571.84	276.
PGC0049	513.89	19.	ARL0003		
PGC0050	648.72	926.	ARL0004		
PGC0051	457.14	1034.	ARL0005	930.76	235.
PGC0052	1077.07	784.	ARL0006	620.17	222.
PGC0053	534.86	184.	ARL0007	1011.31	679.
PGC0054	630.18	222.	ARL0008	232.99	148.
PGC0055	532.19	760.	ARL0009	942.94	694.
PGC0056			ARL0010	759.00	393.
PGC0057	837.15	702.	ARL0011	1137.97	230.
PGC0058	1455.57	420.	ARL0012	729.97	220.
PGC0059	902.35	1508.	ARL0013	1523.44	454.
PGC0060	842.18	547.	ARL0014	430.10	708.
PGC0061	885.36	349.	ARL0015	837.98	957.
PGC0062	727.78	499.	ARL0016	236.88	2163.
PGC0063	440.93	368.	ARL0017	152.83	3737.
PGC0064	819.11	52.	ARL0018	741.00	2065.
PGC0065	955.28	304.	ARL0019	643.72	324.
PGC0066	1433.63	703.	ARL0020	220.03	2602.

Figure 3.1-1. List of Census Tract Attributes for the Washington, D.C. SMSA (Cont'd)

CENSUS TRACT	OWN	RENT	CENSUS TRACT	OWN	RENT
ARL0021	430.09	107.	FAX0011	1335.42	417.
ARL0022	283.88	936.	FAX0012	1399.68	397.
ARL0023	843.10	426.	FAX0013		
ARL0024	546.75	826.	FAX0014	545.12	275.
ARL0025	401.82	770.	FAX0015		
ARL0026	497.20	507.	FAX0016	501.20	658.
ARL0027	103.95	1381.	FAX0017	996.25	1196.
ARL0028	690.90	657.	FAX0018	989.30	115.
ARL0029			FAX0019	1440.87	287.
ARL0030			FAX0020	3093.32	329.
ARL0031	617.70	366.	FAX0021	1900.74	351.
ARL0032	227.01	1926.	FAX0022	573.07	95.
ARL0033	171.06	59.	FAX0023	866.10	700.
ARL0034			FAX0024	1433.63	246.
ARL0035			FAX0025	719.32	118.
ARL0036	623.28	349.	FAX0026	923.34	107.
ARL0037			FAX0027	1125.52	146.
ARL0038	170.03	1520.	FAX0028	963.91	179.
FAX0001	623.91	332.	FAX0029	1191.54	139.
FAX0002	955.23	163.	FAX0030	1034.64	359.
FAX0003	275.06	1003.	FAX0031	1103.76	238.
FAX0004	1732.90	376.	FAX0032	1097.73	215.
FAX0005	2128.13	308.	FAX0033	2421.15	328.
FAX0006	1040.02	534.	FAX0034	739.13	127.
FAX0007			FAX0035	2749.02	631.
FAX0008	224.93	77.	FAX0036	906.87	192.
FAX0009	1846.41	309.	FAX0037	1274.11	191.
FAX0010	1730.21	239.	FAX0038	1433.26	211.

Figure 3.1-1. List of Census Tract Attributes for the Washington, D.C. SMSA (Cont'd)

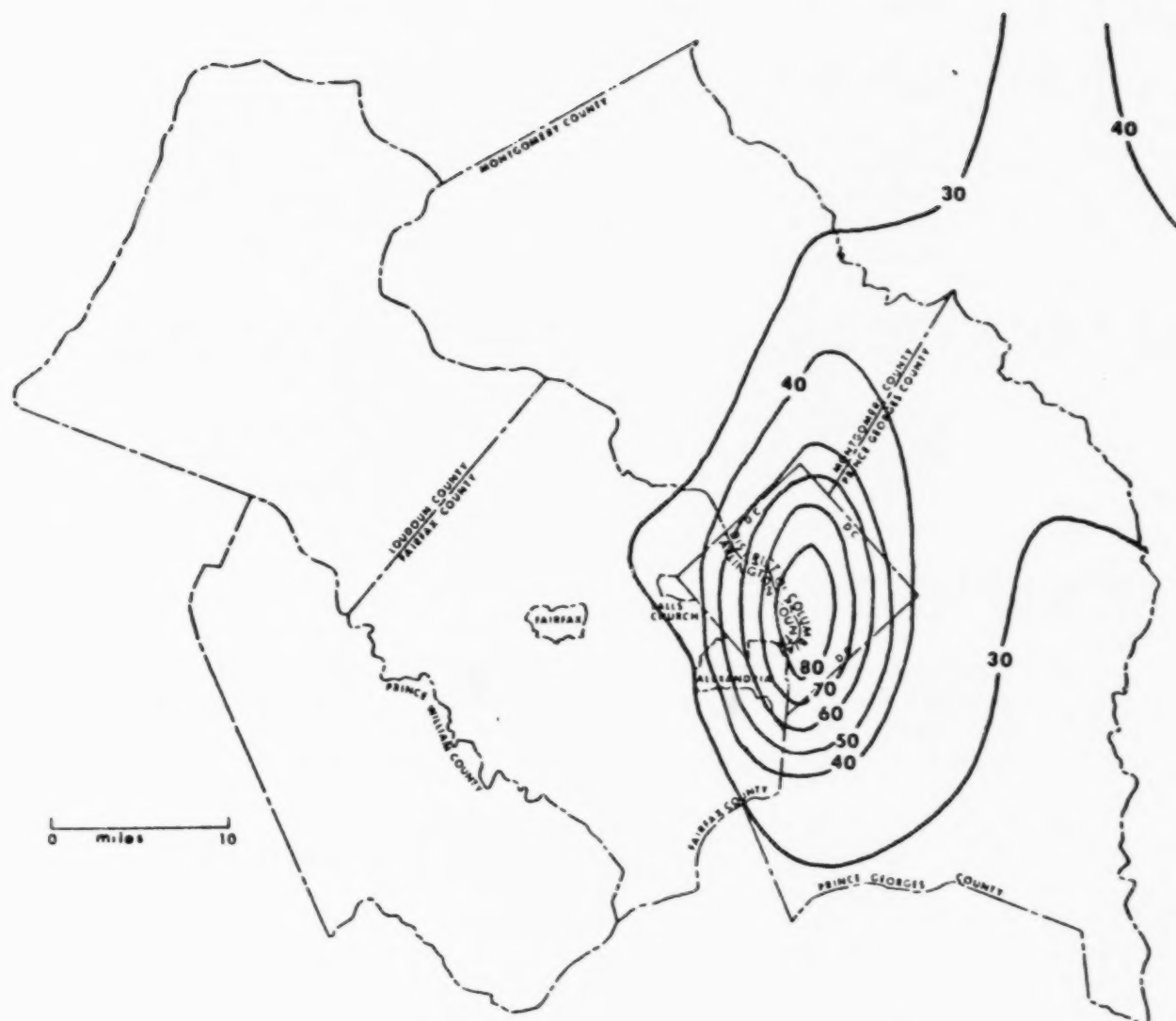
CENSUS TRACT	ϕ WN	RENT
FAX00039	1820.74	232.
FAX00040	1383.53	177.
FAX00041	970.68	278.
FAX00042	755.97	258.
FAX00043	391.11	176.
FAX00044	659.84	244.
FAX00045	381.84	156.
ALX0001	386.84	480.
ALX0002	91.01	612.
ALX0003	519.05	331.
ALX0004		
ALX0005		
ALX0006	823.04	130.
ALX0007	531.13	231.
ALX0008	54.00	951.
ALX0009	27.00	242.
ALX0010		
ALX0011	37.00	1656.
ALX0012	12.00	1499.
ALX0013	1.00	643.
ALX0014	804.32	838.
ALX0015	972.63	398.
ALX0016	495.22	804.
ALX0017	80.96	361.
ALX0018	486.87	1661.
ALX0019	259.04	825.
ALX0020	743.23	2381.
FC0001	502.20	110.
FC0002	801.11	812.
FC0003	447.20	140.

Figure 3.1-1. List of Census Tract Attributes for the Washington, D.C. SMSA (Cont'd)

- P 1 - Existing Control Regulations Throughout the Region - This strategy displays the air quality resulting from complete compliance with existing control regulations in the region.
- P 3 Existing Regulations in the District and Virginia - No Emissions in Maryland. Area source emissions were eliminated and point sources were substantially reduced by the application of maximum control strategy.
- P 18 - Proposed Particulate Control Strategy - District of Columbia sources were controlled to 0.03 grains/scf for industrial process sources, 0.06 grains/scf fuel combustion sources and 0.20 grains/scf for incineration sources. Maryland and Virginia sources were controlled to the level specified by their respective Implementation Plans.
- P 2 - Maximum Control Technology - Under this strategy the best available control device or measure (as defined in the IPP I Control Cost Model) is applied to each pollution source. This strategy may be neither economically nor technically feasible, but does give a potential lower limit on pollutant emissions.

Sulfur Dioxide Strategies

- Existing SO₂-(1970) Air Quality data for SO₂ under existing conditions throughout the region. The ground level SO₂ concentration isopleths for this situation are shown in Figure 3.1-3. This provides the baseline for SO₂ strategies.
- S 10 - 0.06 Grains/scf on Fuel Combustion Sources - 0.03 Grains/scf on All Other Sources of Particulate Emissions. This strategy was designed to allow residual fuel oil combustion without control in well-designed equipment. A further restriction was applied to large coal-fired units (i.e., power generating stations) in that they were required to meet a 0.03 grains/scf standard. (This primary particulate emission strategy tends to produce fuel switching in powerplants which also reduces SO₂ emissions.)
- S 14 - Existing Regulations in the District and Maryland - No Emission in Virginia. Hypothetical display of regional air quality if Virginia's contribution were removed.



NOTE: Annual Concentration in $\mu\text{g}/\text{m}^3$

Figure 3.1-3. Existing Ground Level Sulfur Dioxide Concentrations in the NCIAQCR as Computed by the Verified Diffusion Model

- S 15 - Maximum of 0.7 Percent Sulfur Content Fuel in Region. This gives a small reduction from current 1.0 percent sulfur restriction now in effect in most of the Region. (Major exceptions are the Dickerson and Chalk Point powerplants.)
- S 11 - Existing Regulations. Complete application of existing regulations affecting sulfur oxide emissions throughout the Region.

The above strategies for particulate and SO₂ emissions are listed in order of decreasing total emissions (i.e., total emissions due to point and area sources). The complete average annual ground level receptor concentration data for all of these strategies are too voluminous to present here. Table 3.1-1 summarizes general regionwide values of existing and controlled emissions and the ground level concentration at the maximum receptor.

Included in Table 3.1-1 are the annualized point source control costs for the entire region. These control costs are the only costs employed in the demonstration study. Proposed methods for estimating area sources control costs and other private and public sector costs have been prepared by Woodcock [1971].

The control cost and emission rates (old and new) are available on a regionwide and political jurisdiction basis from the IPP Regional Strategies Program summary table outputs. Samples of these tables are given in Appendix A. The Regional Strategies Program also provides a tabulated summary of emission standard effects on individual source emissions including device costs and emission rates in tons/day (existing, allowable and controlled). In principle, these data can be used to obtain cost/benefit analysis information on an individual source or census tract basis. However, as currently designed, the RAPA Cost/Benefit Model cannot be conveniently used below the political jurisdiction level.

Table 3.1-1. Particulate and Sulfur Oxides Control Strategy Summaries-NCIAQCR.

Strategy/ Pollutant	POINT SOURCES		AREA SOURCES		CONTROL COST		Maximum Receptor ($\mu\text{g}/\text{m}^3$)
	Percent Reduction	New Emission Rate (Tons/Day)	Percent Reduction	New Emission Rate (Tons/Day)	$\$/\text{Ton}$ Removed	$\$/\text{Ton}$ Removed	
Existing Particulates	-	84.7	-	75.6	-	-	107.7
P 1 Particulates	36.3	54.0	18.0	62.0	0.5	47	92.2
P 3 Particulates	62.2	32.0	47.5	39.7	4.0	210	90.0
P 18 ¹ 2 Particulates	70.4	25.0	51.4	36.7	10.8	498	68.2
P 2 ¹ Particulates	87.4	10.7	51.4	36.7	13.9	514	64.2
Existing SO ₂	-	542.0	-	118.6	-	-	99.3
P 10/S 10 ** SO ₂	36.4	344.8	0	118.6	-3.5 ⁴	-48 ⁴	95
S 19 ² 3 SO ₂	43.0	308.9	20.8	93.9	14.7	172.7	68
S 14 SO ₂	55.0	243.9	25.5	88.4	6.1	57.6	77
S 15 ¹ SO ₂	67.4	176.6	31.3	81.4	14.6	109	67
S 11 ¹ SO ₂	100.0	0.0	82.3	21.0	104.5	528	43

**Designed for particulates.

¹Capable of satisfying regional air quality standards.

²Originally proposed strategy for D.C. (Ref. Implementation Plan Report).

³Not used in this demonstration.

⁴See explanation of negative costs in Section 2.3.1.

3.2 ESTIMATION OF DIRECT DAMAGE COSTS

The study of direct damage effects for the RAPA Cost/Benefit Model demonstration involved the use of the Damage Costs Module (Section 2) with the NCIAQCR population, housing and air quality data detailed in the preceding sections of this chapter. A linear model of direct damages and the Pro Forma Damage Functions described in Appendix C were used.

These linear damage functions (shown in Figure 3.2.1 are:

$$D_{SO_2} = 0.66x - 5.90$$

$$D_p = 0.47x - 4.70,$$

where:

D_{SO_2} = Damage per capita in millions of dollars per year due to sulfur dioxide.

D_p = Damage per capita in millions of dollars per year due to particulates.

x = The average annual pollutant concentration (SO_2 or particulates) in micrograms per cubic meter ($\mu g/m^3$).

The results of the cost/benefit analysis on a regional basis have been summarized in Table 3.2-1. The tabulated values are listed by strategy in separate groups for SO_2 strategies (above) and particulate strategies (below). Each set of strategies is listed in increasing order of stringency. For example, the identification S-10" refers to the second SO_2 strategy (employed in this study) in order of stringency. This is referenced number S-10, according to the Washington Implementation Plan Study [TRW, August 1970] identification scheme given in Section 3.1.

The tabulated results include:

- The total emissions (tons/day) - The sum of the contributions of all point (controlled) and area (scaled) sources in the region, (from IPP tabulated output).

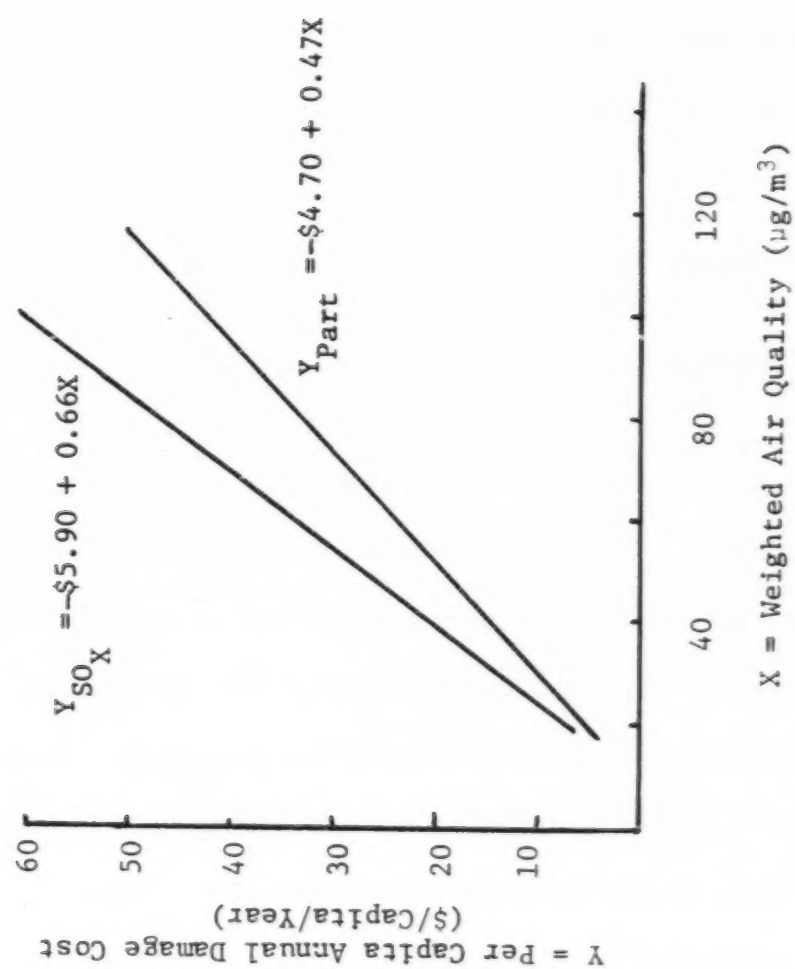


Figure 3.2-1. Pro Forma Functions Utilized in NCIQCR Cost/Benefit Demonstration

Average Air Quality						
Strategy	Total Emission (Tons/Day)	Weighted With Respect To Population ($\mu\text{g}/\text{m}^3$)*	Point Emission (Tons/Day)	Damage ($\$ \times 10^6$)	Benefit ($\$ \times 10^6$)	Control Cost ($\$ \times 10^6$)
<u>SO₂:</u>						
Existing	660.6	65.0	542.0	73.6	0.0	0.0
S-10	463.4	57.8	344.8	64.0	9.6	-3.5
S-14	332.3	52.8	243.9	57.5	16.1	6.1
S-15	238.0	49.3	176.6	52.9	20.7	14.6
S-11	21.0	36.4	0.0	36.0	37.6	104.5
<u>Particulates:</u>						
Existing	160.3	69.4	84.7	55.0	0.0	0.0
P-1	116.0	64.4	54.0	50.8	4.7	0.5
P-3	71.7	60.8	32.0	47.5	8.0	4.0
P-18	61.7	57.5	25.0	44.4	11.1	10.8
P-2	47.4	54.1	10.7	41.2	14.3	13.9

$$\star \frac{\sum(\text{People})(\mu\text{g}/\text{m}^3)}{\sum(\text{People})} = \mu\text{g}/\text{m}^3$$

Table 3.2-1. NCIAQCR - Regional Damage Values Summary

- The air quality weighted with respect to population ($\mu\text{g}/\text{m}^3$) - This value is given by total exposure* divided by the total population of the region and is a good measure of average dosage. The units are actually
$$\frac{\text{people} - \mu\text{g}/\text{m}^3}{\text{people}}$$
 on the annual average basis, (from Damage Costs Module output).
- Total point emissions (tons/day) - The total emissions (controlled) of all the point sources in the region.
- Damage ($\$ \times 10^6$) - The damages in units of millions of dollars per year, as calculated using the (Pro Forma) damage function provided, (from Damage Costs Module output tables).
- Benefit ($\$ \times 10^6$) - Calculated from the existing damage contribution, i.e., the reduction in damages resulting as each control strategy improves air quality.
- Control Cost ($\$ \times 10^6$) - The total annual cost of controlling the point source emissions as calculated by IPP, (from tabulated output).

All costs and damages are on an annual basis. As expected, the total emissions, point emissions, weighted air quality and damages are all monotone decreasing functions of stringency. The control costs are generally monotone increasing functions of stringency. The exceptional case is an infrequent negative cost**. In general, the appearance of negative control cost has been interpreted as probably representing a small positive value.

* The concept of exposure is explained in Chapter 2.0. Briefly, it is the product of the census tract air quality and population, summed over all census tracts in the region; it has the units $\frac{\text{people} - \mu\text{g}}{\text{m}^3}$

**Actually, the use of SO_2 emissions to manufacture sulfuric acid, when applied as a control device in the IPP simulation, can produce negative costs, i.e., profit. However, this is a rare exception and negative costs in the IPP I simulations were generally found to be spurious. They usually result from fuel switching applications. IPP I switched fuels on a specific price per source basis to a general regional price basis. Consistency could not always be met even under the best of conditions; this deficiency has since been corrected in IPP II. However, most of the problems of this kind, even in IPP I, really related to poor fuel price data which did not properly reflect demand for low sulfur fuel or accurately represent price on a BTU basis. Poor fuel price structure data can produce negative costs even when using IPP II.

3.3 ESTIMATION OF PROPERTY VALUE EFFECTS

The property value analysis is based on the output of the Property Value Module of the Benefits Model Segment (Chapter 2.0), using the NCIAQCR population and housing data and the Washington Implementation Plan Study regional strategy and air quality data (IPP I). The additional input required to run the Property Value Module, i.e., the regression coefficients for the four Anderson-Crocker property value equations were obtained from the work of Anderson and Crocker [1970] for Washington, D. C. The complete equations are as follows*:

Type I

$$\begin{aligned}\ln(PV1) = & 3.3901 - 0.0712 \ln(PSN) - 0.0610 \ln(PPT) \\ & + 0.7677 \ln(MFI) + 0.0044 \ln(DLP) \\ & - 0.0106 \ln(OLD) + 0.0251 \ln(NWT) \\ & - 0.0582 \ln(DIS) + 0.0 \ln(MRM)\end{aligned}$$

Type II

$$\begin{aligned}\ln(PV2) = & 1.1617 + 0.0010 \ln(PSN) - 0.1698 \ln(PPT) \\ & + 0.9970 \ln(MFI) + 0.0113 \ln(DLP) \\ & - 0.0213 \ln(OLD) + 0.0321 \ln(NWT) \\ & - 0.0312 \ln(DIS) + 0.9064 \ln(MRM)\end{aligned}$$

Type III

$$\begin{aligned}\ln(PV3) = & 0.2428 - 0.0905 \ln(PSN) + 0.0049 \ln(PPT) \\ & + 0.5109 \ln(MFI) + 0.012 \ln(DLP) \\ & - 0.0606 \ln(OLD) - 0.0043 \ln(NWT) \\ & - 0.0216 \ln(DIS) + 0.0 \ln(MRM)\end{aligned}$$

Type IV

$$\begin{aligned}\ln(PV4) = & 0.4705 - 0.0727 \ln(PSN) - 0.0302 \ln(PPT) \\ & + 0.4650 \ln(MFI) - 0.0054 \ln(DLP) \\ & - 0.0408 \ln(OLD) - 0.0124 \ln(NWT) \\ & - 0.0111 \ln(DIS) + 0.0 \ln(MRM)\end{aligned}$$

*For an explanation of census tract attributes and notation, see Section 2. .

The impact of various air quality levels on Type I property values as predicted by the Property Value Module are summarized for the NCIAQCR in Table 3.3-1; the impact on individual political jurisdictions is described in the tables in Appendix D. Note in Table 3.3-1 that there is a single line of data for each pair of control strategies identified in Column 1; the second and third columns give the weighted air quality which results when these two strategies are applied. Column four gives the regional total Type I property value in millions of dollars. The benefit listed in Column five must be annualized before it can be compared with control costs; a reasonable assumption would be that 10% of these benefits accrue per year. The average Type I property value (Column six) is per owner occupied unit, i.e., it is computed by multiplying the number of owner-occupied units in a given census tract by the median property value for that tract, repeating this multiplication for each tract in the region, adding up the products and dividing by the total number of owner-occupied units in the region. The annualized control costs in the last three columns are from IPP.

The output from the Assignment Module is shown in Table 3.3-2. The data presented is similar to that in the previous table, except that an attempt is made to estimate market effects. Thus, the total bid before shift is simply the total regional property value, ignoring the fact that people are likely to relocate in the face of changing property values.

Assuming that the households with the highest mean family income will select the census tract with the highest median property values (and that the second-highest income will select the census tract with the second highest median property value, etc.) results in the total and average bid

SO ₂ Strategy/ Particulate Strategy	Average SO ₂ Air Quality Weighted With Respect To Population (µg/m ³)*	Average Particulate Air Quality Weighted With Respect To Population (µg/m ³)*	Total Type I Property Value \$x10 ⁶	Total Benefit \$x10 ⁶	Average Type I Property Value \$	Average Benefit Per Household \$	SO ₂ Control Cost \$x10 ⁶	Partic- ulate Control Cost \$x10 ⁶	Total Control Cost \$x10 ⁶
Existing/Existing	66.7	70.9	5,329.	0.0	22,365	0.0	0.0	0.0	0.0
10/1	59.8	65.6	5,401.	72.	22,664.	499.	-3.5	0.5	-3.0
14/3	54.4	61.8	5,448.	47.	22,863.	199.	6.1	4.0	10.1
15/18	40.8	58.1	5,489.	41.	23,034.	171.	14.6	10.8	25.4
11/2	36.5	54.6	5,602.	113.	23,507.	473.	104.5	13.9	118.4

$$* \frac{\Sigma(\text{People})(\mu\text{g}/\text{m}^3)}{\Sigma(\text{People})} = \mu\text{g}/\text{m}^3$$

Table 3.3-1. Type I Property Values: NCIAQCR Regional Summary

SO ₂ Strategy/ Particulate Strategy	Average SO ₂ Air Quality Weighted With Respect To Population (µg/m ³) *	Average Particulate Air Quality Weighted With Respect To Population (µg/m ³) *	Total MPV (\$x10 ⁶)	Average MPV (\$)	Total Type I Bid Before Shift (\$x10 ⁶)	Average Type I Bid Before Shift (\$)	Total Type I Bid After Shift (\$x10 ⁶)	Average Type I Bid After Shift (\$)	Total Difference (\$x10 ⁶)	Average Difference (\$)
Existing/Existing	66.7	70.9	4,172.	17506.	5,329	22365.	4,879.	20,475.	-450.	-1890.
10/1	59.8	65.4	4,172.	17506.	5,401.	22664.	4,941.	20,735.	-460.	-1929.
14/3	54.4	61.8	4,172.	17506.	5,448.	22863.	4,982.	20,907.	-466.	-1956.
15/18	50.8	58.1	4,172.	17506.	5,489.	23034.	5,019.	21,066.	-469.	-1968.
11/2	36.5	54.6	4,172.	17506.	5,602.	23507.	5,100.	21,402.	-501.	-2105.

$$\frac{*L(\text{People})(\mu\text{g}/\text{m}^3)}{L(\text{People})} = \mu\text{g}/\text{m}^3$$

Table 3.3-2. Adjusted Type I Property Values: NCIAQCR, Regional Summary

after shift. In every case, there is a lower total regional (and average) property value after equilibrium has been attained, which is contrary to what is expected. In looking at these results, it was realized that an important model capability, which could account for the apparent error, had been omitted. The current algorithm assumes families from any given census tract can move to any other census tract, i.e., will find sufficient housing units. This may be a credible assumption when the total population of each tract is considered, but it is not valid when looking at market effects on owner occupied units only. The capability of accounting for variation is currently being incorporated into the model.

4.0 REFERENCES

ANDERSON, Robert J. and Thomas D. CROCKER, January 1970: "Air Pollution and Housing: Some Findings," Purdue University, Paper 264.

Bureau of Census, U. S. Department of Housing, 1960: "U. S. Censuses of Population and Housing: 1960," Final Report PHC(1)-166.

LARSEN, Ralph I., January, 1969: "A New Mathematical Model of Air Pollution Concentration Averaging Time and Frequency," Journal of the Air Pollution Control Association, Volume 19, No. 1.

MARTIN, Delance O., and Joseph A. TIKVART, June 1968: "A General Atmospheric Diffusion Model for Estimating the Effects on Air Quality of One or More Sources," Journal of the Air Pollution Control Association, pp. 68-148.

TRW Systems Group, November 1969: "Air Quality Display Model (AQDM)."

TRW Systems Group, November 1970: "Air Quality Implementation Planning Program" (IPP), Volume I Operator's Manual, Volume II Programmer's Manual.

TRW Systems Group, August 1970: "Implementation Plan for Controlling Sulfur Oxide and Particulate Air Pollutants," Report No. 16295.000.

APPENDIX A

THE IMPLEMENTATION PLANNING PROGRAM, CONTROL COST CALCULATIONS

1.0 INTRODUCTION

The Implementation Planning Program (IPP) estimates the direct cost of emission control to the major point sources. These point source control costs provide the only cost data currently utilized by the RAPA Cost/Benefit Model. Thus, IPP serves as the Cost Segment for the Cost/Benefit Model. The details of the cost calculations, as performed in the production version of IPP (IPP II)* are presented here for convenience.

2.0 CONTROL MEASURES AND DEVICE APPLICATION

In general, assignment of a control device to a particular point source depends upon a number of engineering factors related to both the source and device characteristics. Within the Control Cost Program of IPP, device assignment is performed in two basic steps which produce a list of pollution control devices for each point source. The first step involves determining those devices which apply to the general source type (defined by their SIC and process code). The second step requires examination of each source within the SIC and process group to determine which of the applicable devices can actually be assigned (i.e., installed) to the point source. This second list of control devices actually applied to each source

* Air Quality Implementation Planning Program, Vol. I, Operator's Manual, Vol. II, Programmer's Manual, Environmental Protection Agency, National Air Pollution Control Administration, Washington, D. C., Contract No. PH-22-68-60, TRW Systems Group, Washington Operations, November 1970.

includes only those remaining after certain criteria have been satisfied. A list of control devices and measures that are considered in the Control Cost Program is provided in Table A.2-1. The application criteria, device descriptions, Standard Industrial Classification (SIC) and process codes are covered in Volume I of the IPP manual.

IPP contains certain pre-set values for device control efficiencies, cost coefficients and other relevant parameters. These pre-set values (Table A.2-2) may be changed by the user through the input data. The Emission Standards Program of IPP attempts to apply each specified emission standard to every applicable point source. For each applicable source, the allowable emission rate is determined and, based on the control device information provided in the final list from the Control Cost Program, an appropriate device or measure is selected. Final selection of the appropriate control device is based on the following tests:

- (a) If the existing emission rate is less than the allowable emission rate, no device is chosen.
- (b) If not (a), then apply the device which results in a controlled emission less than the allowable emission defined by the standard.
- (c) If more than one device produces sufficiently low emissions, the device having the lowest annualized cost is selected.

When none of the available devices allows the sources to meet a particular emission standard, the most efficient device is selected.

To evaluate the impact of the regionwide emission control strategy on regional air quality, the Regional Strategies Program of IPP adjusts each receptor concentration value by modifying the contribution of each

Table A.2-1. Pollution Reduction Devices or Methods
Applied to Point Sources in IPP.

001	Wet Scrubber - High Efficiency
002	Wet Scrubber - Medium Efficiency
003	Wet Scrubber - Low Efficiency
004	Gravity Collector - High Efficiency
005	Gravity Collector - Medium Efficiency
006	Gravity Collector - Low Efficiency
007	Centrifugal Collector - High Efficiency
008	Centrifugal Collector - Medium Efficiency
009	Centrifugal Collector - Low Efficiency
010	Electrostatic Precipitator - High Efficiency
011	Electrostatic Precipitator - Medium Efficiency
012	Electrostatic Precipitator - Low Efficiency
013	Gas Scrubber
014	Mist Eliminator - High Velocity
015	Mist Eliminator - Low Velocity
016	Fabric Filter - High Temperature
017	Fabric Filter - Medium Temperature
018	Fabric Filter - Low Temperature
019	Catalytic Afterburner
020	Catalytic Afterburner with Heat Exchanger
021	Direct Flame Afterburner
022	Direct Flame Afterburner with Heat Exchanger
027	Eliminate Coal Combustion
028	Eliminate Coal and Residual Fuel Oil Combustion
029	Change all Fuel Use to Natural Gas
030	No Fuel Use Over a Maximum Sulfur Content (Specified by the User in the Regional Data Base)
031	Same as Device 030 but with a Different Allowable Sulfur Content
032	Same as Device 030 but with a Different Allowable Sulfur Content
039	Catalytic Oxidation - Flue Gas Desulfurization
041	Dry Limestone Injection
042	Wet Limestone Injection
043	Sulfuric Acid Plant - Contact Process
044	Sulfuric Acid Plant - Double Contact Process
045	Sulfur Plant

Table A.2-2. IPP Control Device Preset Data

ID	Device Name	Rated Efficiency		Manufacturers Price Coefficient		Install Factor	Chemical Cost	Disposal Cost		Labor Quantity			Device Life	Pressure Drop	Fuel Factor
		SO ₂	Part	1	2	3		SO ₂	Part	SHL	MED	LGE			
1	WET SCRUBBER HI EFFIC	0.0	98.0	0.289E 01	0.228E 00	0.0	0.0	0.0	1.0	0.50	1.00	2.00	15	20	0.0
2	WET SCRUBBER MED EFFIC	0.0	90.0	0.289E 01	0.228E 00	0.0	0.0	0.0	1.0	0.38	0.75	1.50	15	4	0.0
3	WET SCRUBBER LOW EFFIC	0.0	80.0	0.126F 01	0.145E 00	0.0	0.0	0.0	1.0	0.38	0.75	1.50	15	3	0.0
4	GRAV COLLECTOR HI EFFIC	0.0	60.0	-0.445E 00	0.326E 00	0.0	0.0	0.0	1.0	0.25	0.50	1.00	15	0	0.0
5	GRAV COLLECTOR MED EFFIC	0.0	40.0	-0.420E-01	0.155E 00	0.0	0.0	0.0	1.0	0.25	0.50	1.00	15	0	0.0
6	GRAV COLLECTOR LOW EFFIC	0.0	30.0	0.300E-02	0.560E-01	0.0	0.0	0.0	1.0	0.25	0.50	1.00	15	0	0.0
7	CYCLONE HI EFFIC	0.0	85.0	0.241E 01	0.197E 00	0.0	0.0	0.0	1.0	0.25	0.50	1.00	15	4	0.0
8	CYCLONE MED EFFIC	0.0	75.0	0.151E 01	0.137E 00	0.0	0.0	0.0	1.0	0.25	0.50	1.00	15	3	0.0
9	CYCLONE LOW EFFIC	0.0	60.0	0.244E 00	0.990E-01	0.0	0.0	0.0	1.0	0.25	0.50	1.00	15	2	0.0
10	ELECT PRECIP HI EFFIC	0.0	99.0	0.424E 02	0.623E 00	0.0	0.0	0.0	1.0	0.50	1.50	3.00	15	0	0.0
11	ELECT PRECIP MED EFFIC	0.0	95.0	0.312E 02	0.441E 00	0.0	0.0	0.0	1.0	0.50	1.50	3.00	15	0	0.0
12	ELECT PRECIP LOW EFFIC	0.0	90.0	0.197E 02	0.318E 00	0.0	0.0	0.0	1.0	0.50	1.50	3.00	15	0	0.0
13	GAS SCRUBBER	80.0	80.0	0.317E 01	0.251E 00	0.0	10.0	0.0	0.0	0.38	0.75	1.50	15	5	0.0
14	MIST ELIMINATOR HI VEL	0.0	99.0	0.266E 01	0.325E 00	0.0	0.0	0.0	0.0	0.25	0.50	1.00	15	10	0.0
15	MIST ELIMINATOR LOW VEL	0.0	85.0	0.177E 01	0.217E 00	0.0	0.0	0.0	1.0	0.25	0.50	1.00	15	5	0.0
16	FABRIC FILTER HI TEMP	0.0	99.0	0.145E 01	0.831E 00	0.0	0.0	0.0	1.0	0.50	1.25	2.50	15	5	0.0
17	FABRIC FILTER MED TEMP	0.0	99.0	0.348E 01	0.448E 00	0.0	0.0	0.0	1.0	0.50	1.25	2.50	15	5	0.0
18	FABRIC FILTER LOW TEMP	0.0	99.0	0.266E 01	0.325E 00	0.0	0.0	0.0	0.0	0.50	1.25	2.50	15	5	0.0
19	CATALYTIC AFTERBURNER	0.0	95.0	0.755E 01	0.151E 01	0.0	0.0	0.0	0.0	0.25	0.50	1.00	15	1	0.49
20	CATALYTIC AB WITH HE	0.0	95.0	0.755E 01	0.151E 01	0.0	0.0	0.0	0.0	0.25	0.50	1.00	15	1	0.24
21	DIRECT FLAME AFTERBURNER	0.0	95.0	0.571E 01	0.117E 01	0.0	0.0	0.0	0.0	0.13	0.25	0.50	15	1	1.00
22	DIRECT FLAME AB WITH HE	0.0	95.0	0.571E 01	0.117E 01	0.0	0.0	0.0	0.0	0.13	0.25	0.50	15	1	0.40
27	ELIMINATE COAL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0.0
28	ELIMINATE COAL AND R OIL	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0.0
29	SWITCH TO GAS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0.0
30	SULFUR LIMITATION 1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0.0
31	SULFUR LIMITATION 2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0.0
32	SULFUR LIMITATION 3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0.0
39	CATALYTIC OXIDATION	90.0	0.0	-0.124E 02	0.167E 01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0	0	0.0
41	DRY LIMESTONE INJECTION	50.0	0.0	0.0	0.995E-06	-0.603E-16	0.0	0.0	0.0	0.0	0.0	0.0	15	41	0.0
42	WET LIMESTONE INJECTION	80.0	98.0	0.111E-05	0.481E-16	0.0	2.0	0.0	0.0	0.0	0.0	0.0	15	0	0.0
43	H2504 PLANT-CONTACT	97.5	0.0	0.0	0.800E 00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20	0	0.0
44	H2504 PLANT-2 CONTACT	99.5	0.0	0.0	0.800E 00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20	0	0.0
45	SULFUR PLANT	95.0	0.0	0.0	0.810E 00	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20	0	0.0

source according to its "new" emission rate. The "new" emission rate for each source is determined as follows:

- (a) If the existing emission rate is less than the allowable emission, the existing emission rate is used. Otherwise the allowable emission rate under the appropriate emission standard is used*.
- (b) For area sources, the scale factor (user supplied input) is applied to the existing emission rate and the resulting emission rate is used by the program in the determination of new air quality. However, no cost estimates are made for control of area sources.

* This is only true for IPP II. The rationale is that in practice, it is technically possible to supply, and sources will purchase devices which meet requirements only. IPP I used the controlled emission rate to determine new air quality. The controlled rate may be less than the allowable rate due to the limited number of devices and parameters that can be dealt with in practice in the simulation.

3.0 CONTROL COST CALCULATIONS

The total annual cost resulting from the assignment of a control device to a point source involves the component costs: purchase cost, installation cost, interest charges, and operating and maintenance costs. The calculations as performed in IPP involving each of these component costs are described in the subsections below.

In addition to the control devices described, a set of emission control methods have been included in the Control Cost Program. These methods are designed to provide a reduction in combustion source emissions by using fuel substitutions to modify the existing fuel use pattern.

3.1 PURCHASE COST

The purchase cost of control devices depends, in general, upon the characteristics and complexity of the control device and the size of the pollution source to be controlled. In the Control Cost Program, these parameters are used to determine a basic purchase cost equation for each control device. The general form of this equation is:

$$y = a + bx + cx^2,$$

The coefficients a, b and c in this equation correspond to "Manufacturer's Price Coefficient" 1, 2 and 3, in Table A.2-2, respectively.

When the corrosive gas stream from acid manufacturing facilities are controlled, more expensive control device construction materials must be used. For these cases the Control Cost Program, utilizes the following factors to increase the device purchase price:

If exit temperature $\leq$ 330°F, multiply purchase cost by 1.7.
If exit temperature $>$ 300°F, multiply purchase cost by 5.0

3.2 INSTALLATION COST

The cost of installing a control device on a particular source is calculated on the basis of an installation cost factor. This factor is expressed as a percentage of the purchase price and is a user input item for each control device. The program sums purchase cost and installation charge to determine the total installed cost for each source-device combination.

For some control device installations, however, extensive modifications of the source are required and it is not possible to identify a purchase cost figure independent of the installation charge. For these devices, the total installed cost is estimated by the purchase price equations described in Subsection 3.1. No additional factor is required in these cases to account for installation at a source site. Devices in this category are the flue gas desulfurization units (039, 041, 042) and by-product manufacturing facilities (043, 044, 045).

3.3 ANNUAL CAPITAL CHARGE

After the total installed cost (purchase plus installation) of a device has been determined, an annualized capital charge is calculated, based on the user inputs: rated life of the control device and prevailing

interest rate. Therefore, the annual cost comprises both depreciation of the initial total investment (installed cost from Subsection 3.2) and the interest costs.

The particular accounting technique employed here is called the Capital Recovery Factor (C.R.F.). The use of the C.R.F. allows the write-off of the initial investment to be divided into a uniform series of end-of-year payments.

The C.R.F. multiplied by the initial investment cost (debt) determines the uniform end-of-year payments necessary to repay the debt in "N" years (the rated life of the device) with an interest rate "i" (decimal equivalent). The C.R.F. is calculated by the following relation:

$$C.R.F. = \frac{i(1+i)^N}{(1+i)^N - 1}$$

The annual capital charge is then computed to be the product of the total installed cost and the C.R.F. value.

In practice, the capital recovery concept operates as follows:

- (1) Payments are made at the end of each year in the amount determined by multiplying the capital recovery factor by the initial debt.
- (2) Interest payments are made to the bondholders at the end of each year in the amount determined by multiplying the interest rate by the initial debt.
- (3) The difference between the equal annual payments and the interest payments to the bondholders is placed into a depreciation account where it is assumed to draw interest at the same rate paid to the bondholders.

The total yearly cost to the source for controlling pollution by means of a specified device is then the sum of the annual capital charge and the annualized operating and maintenance expense discussed in the next subsection.

3.4 OPERATING AND MAINTENANCE EXPENSE

Operating and maintenance (O&M) expenses are usually a major portion of the annualized control device cost. The factors which must be considered in determining the annual O&M cost of a particular source-device combination consist of: the amount of power (calculated as electrical power) necessary to maintain the effluent gas flow through the control device, the quantity of labor required, the cost of liquid or additional fuel used by the device, and the cost or credit resulting from disposal of the collected pollutant. These factors are used in the following equations to determine the O&M cost for each type of control device pre-set in IPP.

For control devices 001 through 022, a single equation is used to compute the annual O&M cost:

$$O\&M = AB + CD + EF + GI + JK + LM,$$

where A = electricity quantity (kwhr/yr)	(a)*
B = electricity cost (\$/kwhr)	(input as regional data)
C = water quantity (gal/yr)	(b)
D = water cost (\$/gal)	(input as regional data)
E = chemical quantity (ton/yr)	(c)
F = chemical cost (\$/ton)	(input as device data)
G = fuel quantity (cu.ft./yr)	(d)
I = fuel cost (\$/cu. ft.)	(natural gas value, input as regional data)
J = disposal quantity (ton/yr)	(e)
K = disposal cost (\$/ton)	(input as device data)
L = labor quantity (hr/yr)	(f)
M = labor cost (\$/hr)	(input as regional data)

*The letters refer to the following items which describe the computation of these data elements.

The computation of these data elements are as follows:

(a) Electricity Quantity (kwhr/yr) = $(1.955 \cdot 10^{-4}) p V H$

where p = pressure drop (in H_2O)

V = exhaust gas volume (ACFM) this is the new computed volume (x) in the case of a wet device

H = operating hours (hr/yr)

If the device is one of the electrostatic precipitators (010, 011, 012), the following quantities are added to the electricity quantity:

Device 010, add $(0.34 \cdot 10^{-3}) V H$

Device 011, add $(0.26 \cdot 10^{-3}) V H$

Device 012, add $(0.19 \cdot 10^{-3}) V H$

(b) Liquid Quantity (gal/yr) = $(3.0 \cdot 10^{-2}) V H$

The liquid quantity is only computed for wet devices (001, 002, 003, 013). For these cases the exhaust gas volume (V) will always be the new computed volume.

(c) Chemical Quantity (ton/yr) = $P_s H$

where P_s = amount of SO_2 removed by the device [(ton/day)/(8*shifts)]

(d) Fuel Quantity = $f V H$

where f = 0.490, if device 019

0.245, if device 020

1.000, if device 021

0.404, if device 022

0.000, all other devices

It should be noted that additional fuel is only used for the catalytic and direct flame afterburners. The program assumes that the additional fuel is natural gas.

- (e) Disposal Quantity - Emission rate for pollutant in question (tons/day) times new device efficiency (after adjustment) for same pollutant times 365 (days/year).

This is computed for each of the pollutants.

- (f) Labor Quantity = LH

Where H = operating time (hr/yr)

L = labor (labor hours/operation hours)

There are four, user input, labor values which relate to the source size being controlled (small, medium, large, and extra large). Source size is measured by V, actual cubic feet of exhaust gas per minute (as corrected). The program selects the appropriate value as follows:

Use the "small" value for $V \leq 40,000$

Use the "medium" value for $40,000 < V \leq 250,000$

Use the "large" value for $250,000 < V \leq 1,000,000$

Use the "extra large" value for $V > 1,000,000$

For any particular control device, only some of the terms in the above equation will be non-zero. An electrostatic precipitator, for instance, will not use liquid, chemicals, or additional fuel. The quantity JK however, will always be calculated.

Operating and maintenance costs for the remaining control devices cannot be estimated by the above calculations. These devices are generally more complex (involving sulfur oxide removal), and separate equations have been developed to compute their O&M expenses. These equations are based on manufacturers' specifications and operating experience reported in the literature.

For the three flue gas desulfurization measures considered, the following calculations of operating cost are used.

Device 039 - Catalytic Oxidation

$$\text{O\&M} = 0.05 \cdot (\text{total installed cost}) + \text{AB} + \text{JK}$$

Where A, B, J, and K are as defined above.

Device 041 - Dry Limestone

$$\text{O\&M} = 365 P_c (0.17 + 7.0 SC_c) + 25,000$$

Device 042 - Wet Limestone

$$\text{O\&M} = 365 P_c (0.196 + 3.82 SC_c) + 130,000$$

where P_c = coal burned in ton/day (Source File)
 S = coal sulfur content, decimal (Source File)
 C_c = chemical cost in \$/ton (input as device data)

The O&M costs associated with the use of sulfuric acid or sulfur by-product manufacturing as a pollutant control measure (devices 043, 044, and 045) are computed from the following equation:

$$\text{O\&M} = \text{JK} - (\text{Purchase Cost})/(\text{Rated Life}) + y$$

where, for each device:

J = disposal quantity, as calculated in item (e) above,

K = input disposal cost

Purchase Cost = value computed in Subsection 3.1, Item (f)

Rated Life = input as device data

y = value as calculated below. The variable P used in these computations is the percentage concentration of sulfur dioxide, by volume, in the exhaust gas as given in Subsection 3.1, item (f).

Devices 043, 044 - Sulfuric Acid Plant - Single Contact and Double Contact Process

$$\log_{10} y = 0.75 \log_{10} x + a$$

where y = annual cost (in 10^6 \$)

x = sulfur emission in ton/day

if $0 \leq P < 3.0$, then $a = 1.6903$

$3.0 \leq P < 6.0$, then $a = 1.4445$

$6.0 \leq P < 10.0$, then $a = 1.2076$

$P > 10.0$, then $a = 1.721$

Device 045 - Sulfur Plant

$$\log_{10} y = 0.81 \log_{10} x + a$$

where y = annual cost (in 10^6 \$)

x = sulfur emission (above)

if $0 \leq P < 5.0$, then $a = -1.210$

$5.0 \leq P < 7.0$, then $a = 1.375$

$P \geq 7.0$, then $a = 1.435$

In addition to the O&M costs described in this Subsection, the program calculates the cost of necessary cooling of the effluent gas stream prior to device application. This cost is calculated whenever the temperature of the gas entering the cooling device (approximated by the exhaust gas temperature) exceeds 532°K (500°F). The cost computations, performed for each source assigned device combination, are as follows:

If exhaust gas volume is greater than or equal to 2000 ACFM but less than 6800 ACFM,

$$\begin{aligned} \text{Cost (\$)} = & 1131.7 \left[e^{[.436 \ln (s/1000)]} \right] + 124 + .07185 S' \\ & + S[(.0003225 + .000016286 \frac{.24T - 71.2}{T}) H \\ & + \frac{.0000019 (.24T - 71.26) H}{T} + .04] \end{aligned}$$

If exhaust gas volume is greater than or equal to 6800 ACFM but less than 100,000 ACFM

$$\begin{aligned} \text{Cost } (\$) = & 720.17 \left[e^{[.668 \ln (S/1000)]} \right] + 124 + .07185 S' \\ & + S[(.0003225 + .000016286 \frac{.24T - 71.2}{T}) H \\ & + \frac{.0000019 (.24T - 71.2)}{T} H + .04] \end{aligned}$$

where

S = exhaust gas volume (ACFM)

S' = volume of cooled gas to control device (ACFM @ 500°F)
= S[526.2 + .023T]/T

H = operating hours per year

= 365 · (number of shifts/day) · 8

T = exhaust gas temperature (°K)

If the gas volume is less than 2000 ACFM the program will not apply the device being considered, and will go on to the next assigned device.

If the gas volume is greater than 100,000 ACFM, the program will divide the ACFM value into equal parts, each of which is less than 100,000 ACFM. The gas cooling data will then be calculated using the procedure described above. The resulting cost and cooled exhaust gas volume is then multiplied by the number of equal parts to produce the total values for the device.

The costs calculated above combine purchase, installation, and operating costs for the gas cooling measure (assumed to be of the water spray type) and are on an annualized basis. The new exhaust gas volume (S') and new exhaust gas temperature (532°K) become the new source-device characteristics.

The total annual device cost, output by the program, is then the annual capital cost (defined in Subsection 3.3) plus the O&M cost and, if applicable, the gas cooling cost described in this subsection.

3.5 FUEL PARAMETERS AND GENERAL CALCULATIONS

The fuel substitution portion of the Control Cost Program uses the data items shown in Table A.3-1 (obtained from the locations indicated).

Prior to entering a specific fuel substitution routine, the program calculates the following quantities in the manner shown. These quantities are calculated once for each point source and are used later in the various fuel substitution calculations.

- (1) BTU contribution of each fuel burned, B_i^+
 - (a) $B_i(\text{BTU/year}) = A_i H_i (\text{Boiler Eff})_i 365^*$
- (2) Annual cost of each fuel burned, P_i
 - (a) $P_i(\$/\text{year}) = C_i A_i 365$
- (3) Potential emission from each fuel burned, E_{ji}^{**}
 - (a) $E_{SC}(\text{ton/day}) = 19.0 A_C S_C 10^{-3}$
 - (b) $E_{SR}(\text{ton/day}) = 79.3 A_R S_R 10^{-6}$
 - (c) $E_{SD}(\text{ton/day}) = 71.8 A_D S_D 10^{-6}$
 - (d) $E_{SG}(\text{ton/day}) = 0.2 A_G 10^{-9}$
 - (e) $E_{PC}(\text{ton/day}) = 0.5 A_C a f_1 10^{-3}$
 - (f) $E_{PR}(\text{ton/day}) = 0.5 A_R f_2 10^{-6}$

[†]See Table A.3-1 for subscript identification.

^{*}See Table A.3-2 for $(\text{Boiler Eff})_i$ values.

^{**}See Tables A.3-3 and A.3-4 for f_1 and f_2 values, respectively.

Table A.3-1. Fuel Parameters

<u>Symbol</u>	<u>Variable Name</u>	<u>Units</u>	<u>Where Obtained</u>
--	Source ID number	--	Source data
A _i	Amount of each existing fuel burned	Tons, gallons, cu. ft. per day*	Source data
S _i	Sulfur content of each existing fuel burned	Percent by weight	Source data
H _i	Heat content of each existing fuel burned	BTU per ton, gallon or cu. ft.*	Source data
a	Ash content of coal burned	Percent by weight (decimal equivalent)	Source data
D _j	Existing device efficiency for each pollutant	Decimal fraction	Source data
e _j	Emission rate for each pollutant	Tons per day	Source data
C _i	Unit cost of each existing fuel burned	Dollars per ton, gallon, cu. ft.*	Region data
S _{Ni}	Sulfur content of each new fuel available	Percent by weight (decimal equivalent)	Region data
H _{Ni}	Heat content of each new fuel available	BTU per ton, gallon or cu. ft.*	Region data
a _N	Ash content of each new coal available	Percent by weight	Region data
MA _i	Maximum allowable sulfur content for each fuel type	Percent by weight	Region data

i subscripts refer to type of fuel (C - coal, R - residual oil, D - distillate oil, G - gas)

j subscripts refer to pollutant (S - SO_x, P - particulate)

* For coal, oil and gas respectively.

Table A.3-2. Boiler Efficiencies

<u>BTU Range</u>	<u>Efficiency</u>			
	<u>Coal</u>	<u>Residual Oil</u>	<u>Distillate Oil</u>	<u>Natural Gas</u>
Annual BTU Output $\geq 0.1 \times 10^9$	.87	.86	.86	.82
Annual BTU Output $< 0.1 \times 10^9$	.75	.77	.77	.80

NOTE: Boiler efficiencies are utilized in the following manner to calculate the amounts of new fuel required:

1. Assume annual BTU $> 0.1 \times 10^9$
2. Use efficiencies from first row.
3. Compute: $H_i A_i \text{Eff}_i$ for each fuel (i) and total them together
4. If total in No. 3 is less than 0.1×10^9 , then the initial assumption (step 1) was incorrect and the computation is redone using the set of efficiencies from the second row.

Table A.3-3. (f_1) Coal Particulate Emission Factors

Process No.	Combustion Type	f_1
00	All types not listed	15
10	Pulverized, general	16
20	Pulverized, Dry bottom	17
30	Pulverized, Wet bottom without fly ash reinjection	13
40	Pulverized, Wet bottom with fly ash reinjection	24
50	Cyclone	2
60	Spreader Stoker without fly ash reinjection	13
70	Spreader Stoker with fly ash reinjection	20
80	All other stokers	5
90	Hand fired	$20/a^*$

* a = ash content of coal burned, percent by weight (decimal equivalent).

Table A.3-4. (f_2) Oil and Gas Particulate Emission Factors

<u>Fuel</u>	<u>SIC Codes*</u>		
	<u>4911</u>	<u>2xxx, 3xxx</u>	<u>All Other</u>
Residual Oil	8	23	23
Distillate Oil	6.5	15	15
Natural Gas	15	18	19

*A list of Standard Industrial Classification (SIC) Codes and process Codes are given in Air Quality Implementation Planning Program - Volume I Operators Manual, Contract No. PH 22-68-60, November 1970.

$$(g) \quad E_{PD}(\text{ton/day}) = 0.5 A_d f_2 10^{-6}$$

$$(h) \quad E_{PG}(\text{ton/day}) = 0.5 A_G f_2 10^{-9}$$

S_C , S_R , S_D and a are all expressed as a percent (i.e., a number between 0 and 100). The coefficients were obtained by combining conversion dimensional factors with appropriate emission factors (generated by HEW).

To insure the compatibility of the input data, the program next compares the input total emission rates (e_j) with the calculated fuel emission rates (E_j). This comparison is made as follows (where the emission rates have been corrected for any existing control devices):

$$(a) \quad (E_{SC} + E_{SR} + E_{SD} + E_{SG}) (1 - D_S) = E_S$$

$$(b) \quad (E_{PC} + E_{PR} + E_{PD} + E_{PG}) (1 - D_P) = E_P$$

If $0.8 \leq \frac{E_S}{e_S} \leq 1.2$ and $0.8 \leq \frac{E_P}{e_P} < 1.2$, then the input data is assumed to be correct for the purposes of this test. However, if the ratio of the emission rates is not within these limits for either pollutant, the program terminates operations on that source, prints the following data, and begins operating on the next source:

(Source ID Number) - fuel data error - E_j = (Calculated Emission Rate)

e_j = (Input Emission Rate)

After making these calculations, the program begins application of specific fuel substitution measures.

3.6 SPECIFIC FUEL SUBSTITUTION MEASURES

The program contains three fuel elimination methods (Devices 027, 028, and 029) and three fuel sulfur content limitation methods (Devices

030, 031, and 032). The fuel elimination methods are primarily intended to control particulate emissions and as a result, are likely to yield misleading results if applied to sulfur oxides emissions.

The operational characteristics of the fuel substitution measures are as follows:

(a) (Device 027) Elimination of Coal

This method converts any coal which a source may be burning to residual oil, distillate oil, or natural gas with an equal or lower sulfur content. If the source is not burning coal (i.e., $B_C = 0$), this method is inapplicable and the program moves to the next control method. If the source is burning coal (i.e., $B_C \neq 0$), the program examines the alternate fuel information in the regional data, and picks the grade of residual oil with the highest sulfur content less than or equal to the sulfur content of the coal being replaced. In the event there is no residual fuel oil in the region data input which satisfies the above requirements, the program will examine distillate oil and attempt, in the same manner as above, to select an alternate fuel. If no distillate oil is available which meets the requirements, the program switches to natural gas (if available) as the only possible alternate fuel. If gas is not available, the program moves to the next control method. In this case the program prints an error message to the effect that the specified fuel substitution could not be made. The quantity of new (substituted) fuel needed is determined by the requirement that the usable heat input (BTU/hr) must remain unchanged after the fuel substitution.

(b) (Device 028) Elimination of Coal and Residual Oil

This control method operates in the same manner as Device 027, except that the first fuel switch attempted (from coal and residual oil) is to the proper grade of distillate oil.

(c) (Device 029) Elimination of Coal and All Fuel Oil

This control method operates in the same manner as Device 027, except that all existing fuels are switched to gas.

(d) (Devices 030, 031, 023) Fuel Limitation Based on Maximum Allowable Sulfur Content

The three fuel sulfur content limitation methods differ only in that a unique set of allowable sulfur content levels may be input for each method. For each method, an allowable sulfur content for coal, oil and gas must be input.

The program is designed to replace existing high sulfur content fuels with lower sulfur content fuels (of the same type if possible) taken from the input region data base.

The basic series of steps followed by the program for assigning fuel usage under the various sulfur limitations are outlined below:

- (1) Each existing fuel being burned is examined to determine if the specified sulfur limitation is exceeded.
- (2) If the limit is exceeded, then a search is made of the regional data base for a fuel of the same type (i.e., coal, residual oil, etc.) having the proper percent sulfur.
- (3) If no fuel of the same type meets the requirements, then alternate fuel types are considered. Alternate fuel types are examined in the following order until a suitable fuel is found: Residual Oil (grades 1 through 5), Distillate Oil (grades 1 through 3), and Natural Gas.

3.7 FUEL SUBSTITUTION COMPUTATIONS

After a suitable fuel grade has been determined, the Control Cost Program carries out a series of calculations leading to the determination of the cost and the various fuel use and emission parameters. The first step is to compute the amount of each new fuel required. This is accomplished through use of the annual cost (P_i) and annual BTU contribution (B_i), as calculated in Subsection 3.5. The specific procedure for the fuel elimination and sulfur content limitation methods are as follows:

Devices 027, 028, 029

For these devices, the total usable heat produced by the eliminated fuels ($B_i, i = C \text{ and/or } R \text{ and/or } D$) must equal the total usable heat produced by the substitute fuel ($B_{Ni}, i = R \text{ or } D \text{ or } G$), i.e.,

$$\sum B_i = B_{Ni}$$

Substitute fuels are sought having the same or lower sulfur content as the fuel to be eliminated. If these requirements cannot be satisfied for a given fuel substitution, the program will attempt to meet the conditions with a more costly fuel substitution (e.g., for device 027, if residual oil is not acceptable switch to distillate oil is attempted).

Devices 030, 031, 032

For the sulfur limitation methods, a number of fuels may be eliminated in favor of a number of others, but the substitutions are made on a one-for-one basis so that the usable heat produced by an eliminated fuel will be exactly matched by the usable heat produced by the corresponding substitute fuel, i.e.,

$$B_{Ni} \text{ (i=C,R,D, or G)} = B_i \text{ (i=C,R, or D)}$$

The process is repeated until the requirements are met or the fuel types available for substitution are exhausted, in which case the program will print a message to the user and go on to the next control method (device) in the table.

The amount(s) of new fuel(s) is then determined from the following equation:

$$A_{Ni} = \frac{B_{Ni}}{H_{Ni}(\text{Boiler Eff.})H_{Ni}} \text{ (i = C,R,D, or G)}$$

The annual cost of each new fuel is then computed as:

$$P_{Ni} = A_{Ni} C_{Ni}.$$

Summing P_{Ni} for all new fuels used gives the annual cost of the fuel(s). The annual costs of the fuels to be eliminated (P_i) are then summed. The total additional annual fuel cost (C_{add}) is the total new fuel sum minus the total old fuel sum.

The new (controlled) emission rates are now calculated by use of the following equations:

$$\begin{aligned}
 e_{NS} = & \frac{e_S}{1-D_S} - E_S + (19.0 A_{NC} S_{NC} 10^{-3}) \\
 & + (79.3 A_{NR} S_{NR} 10^{-6}) + (71.8 A_{ND} S_{ND} 10^{-6}) \\
 & + (0.2 A_{NG} 10^{-9}) (1 - D_S) \\
 e_{NP} = & \frac{e_P}{1-D_P} - E_P + (0.5 A_{NC} a_N f_1 10^{-3}) \\
 & + (0.5 A_{NR} f_2 10^{-6}) + (0.5 a_{ND} f_2 10^{-6}) \\
 & + (0.5 A_{NG} f_2 10^{-9}) *
 \end{aligned}$$

The decimal efficiencies of the control method are calculated from:

$$D_{NS} = 1 - \frac{e_{NS}}{e_S} ; D_{NP} = 1 - \frac{e_{NP}}{e_P}$$

The final calculations for the fuel substitution methods consist of: (1) summing the total fuel, by fuel category, used by the source after application of each method and (2) for devices 030, 031, and 032, calculating the sulfur dioxide allowable emission rate.

The sulfur dioxide allowable emission rate for devices 030, 031, and 032 is based upon the existing source emissions and upon the existing and allowable sulfur content. If a source already uses fuel with a sulfur content at or below the allowable levels then the allowable emission rate is set equal to existing emissions. If sulfur content levels higher than the maximum allowable are being used then the following computation is carried out for each fuel type.

*Thus, in general

$$e_{Ni} = \left[\frac{e_j}{1-D_j} - E_j + E_{Nj} \right] (1 - D_j)$$

$$\text{Allowable Emission}_i = \text{Existing Emission}_i \frac{\text{Allowable Sulfur Content}_i}{\text{Existing Sulfur Content}_i}$$

where the existing emission rate used in this equation represent the emissions from a particular fuel type. These allowable emissions are then summed by fuel type to provide an overall allowable source emission rate under the sulfur content limitation specified by the control measure.

BLANK PAGE

APPENDIX B

SOURCES OF CENSUS TRACT INFORMATION REQUIRED FOR RAPA COST/BENEFIT MODEL

1.0 INTRODUCTION

The census data contains information that can be expressed in terms of census tract attributes. Table B.1-1 contains a list of census tract attributes most of which have been identified for cost/benefit analyses purposes by T. C. Crocker^{1,2} (notation follows that of Crocker). This list although not complete, is fairly extensive. However, only those attributes indicated by an asterisk have found application in the present model. Crocker² has identified additional census tract attributes which are of importance, but are not available from the censuses of population and housing. These include:

- AMD - the averages (arithmetic mean) monthly dustfall by census tract.
- SOT - the average (arithmetic mean) monthly sulfur dioxide concentration
- CRM - provides a measure of the crime rate; available for Washington, D. C. from a Congressional hearing Crime in the District of Columbia (1965).
- SCH - the annual expenditure per student.
- TAX - the tax rate; available for Washington, D. C., from D. C. Appropriations for 1965: Hearings before Subcommittee on Appropriations, U. S. Senate, 98th Congress, 2nd Session Vol. L, W.D.C. (1965) p. 350.

¹ Air Pollution and Housing: Some Findings, by R. J. Anderson and T. D. Crocker, Paper No. 264, January 1970, Graduate School of Industrial Administration, Purdue University, Lafayette, Indiana.

² T. D. Crocker, Private Communication.

The census tract attributes required for the RAPA Cost/Benefit Model (those indicated by an asterisk in Table B.1-1) are obtainable by the two methods described in the remainder of this appendix.

Table B.1-1. Census Tract Attributes, Notation and Definitions

<u>Attribute</u>	<u>Description</u>	<u>Census Table</u>
AGE	The median age for all males.	(P-3)
ALL*	The number of all housing units.	(H-1)
BMT	The number of housing units with a basement.	(H-1)
BTH	The number of housing units with more than one bathroom.	(H-1)
CAR	The number of units whose residents have no automobiles available.	(H-2)
CLK	The number of clerical and sales workers, i.e., the sum of the clerical and kindred workers and the sales workers classification in Table P-3 of population and housing censuses.	(P-3)
CTY	The number of workers who work in the central city.	(P-3)
DIS*	The distance (to the nearest half mile) from downtown of city center to middle of census tract.	(Map)**
DLP	The number of dilapidated housing units.	(H-1)
FRM	The number of units of less than four rooms.	(H-1)
MCR*	Median contract rent of renter occupied units. Contract rent is the rent agreed upon regardless of any furnishing, utilities or services that may be included.	(H-2)
MFI*	Median family income for families only.	
MGR*	Median gross rent of renter occupied units. Gross rent is the contract rent plus the average monthly cost of utilities (water, electricity, gas) and fuels such as wood, coal and oil if these items are paid for by the renter in addition to the contract rent.	(H-2)
MIL*	Number of square miles in the census tract	(Map)
MPV*	Median property value of owner-occupied housing units. Value is the owner's estimate of how much the property would sell for on today's market (April 1960 for present study). This category is restricted to property with only one housing unit and no-business.	(H-2)

**"Map" refers to map supplied with published census tract tables.

Table B.1-1. Census Tract Attributes, Notation and Definitions
(Continued)

<u>Attribute</u>	<u>Description</u>	<u>Census Table</u>
MRM*	Median number of rooms.	(H-1)
MSC	Median school years completed.	(P-11)
MVD	Number of units having residents who moved in from 1958 to March 1960.	(H-2)
NEW	Number of units ten years old or less.	(H-1)
NWT*	Total number of nonwhite occupied units, i.e., the sum of nonwhite owner occupied and nonwhite renter occupied units.	(H-1)
OLD*	Number of units more than ten years old.	(H-1)
OWN*	Number of all owner occupied housing units	(H-1)
POP*	Total population	(D-1)
RENT*	Number of all renter occupied housing units.	(H-1)
RET	Number of males (white and nonwhite) 65 years or older.	(P-2)
SAL	Number of salaried workers, i.e., the sum of the professional, technical, and kindred workers and managers, officials, and proprietors, including farm classifications, (Male and Female summed).	(P-3)
SFH*	Number of single family housing units, i.e., housing with only one unit in the structure.	(H-1)
SKL	Number of skilled workers, i.e., the number of workers in the craftsmen, foremen, and kindred workers classification, (Male and Female summed).	(P-3)
SND	Number of sound housing units with all plumbing facilities.	(H-1)
SSK	Number of semi-skilled workers, i.e., the number of workers in the operatives and kindred workers classification. (Male and Female summed).	(P-3)
UEM	Number of unemployed persons. (Male and Female summed).	

Table B.1-1. Census Tract Attributes, Notation and Definitions
(Continued)

<u>Attribute</u>	<u>Description</u>	<u>Census Table</u>
USK	Number of unskilled workers, i.e., the sum of the private household workers in the operatives and kindred workers classification, (Male and Female summed).	(P-3)
VAC	Number of available vacant housing units.	(H-1)
WKR	Number of civilian workers, (Male and Female summed).	(P-3)

*

- Tables P-1, P-2, P-3 present population characteristics for all tracts.
- Tables H-1 and H-2 present housing characteristics for all tracts.
- All tabulated results from:
 - U. S. Censuses of Population and Housing: 1960
 - Final Report PHC (1) - 166.
 - U. S. Department of Commerce
 - Bureau of Census

2.0 BUREAU OF THE CENSUS TABULATED SUMMARIES

A reliable but laborious technique of obtaining the attributes for each census tract is to reduce them manually from the tabulated summaries of the censuses of population and housing available from the Bureau of the Census. Samples of the important tables from this source are shown in Figure B.2-1. Annotations have been provided to indicate the sources of the major census tract attributes given in Table B.1-1.

Figure B.2-1

Sample Tables from the Censuses of
Population and Housing with Annotations.

(Asterisk (*) denotes statistics based on 25-percent sample. Population per household not shown where less than 50 persons in households.
Median not shown where base is less than 200)

SUBJECT	TRACT 0001	SUBJECT	TRACT 0001
RACE AND COUNTRY OF ORIGIN		*SCHOOL ENROLLMENT*	
TOTAL POPULATION	947	TOTAL ENROLLED: 5 TO 34 YEARS OLD	1 063
WHITE	4 661	KINDERGARTEN	46
NEGRO	284	PUBLIC	39
OTHER RACES	2	ELEMENTARY (1 TO 8 YEARS)	433
BORN IN PUERTO RICO	12	PUBLIC	372
PUERTO RICAN PARENTAGE	32	HIGH SCHOOL (11 TO 14 YEARS)	312
		PUBLIC	236
TOTAL FOREIGN STOCK	1 103	COLLEGE	92
FOREIGN BORN	343		
NATIVE FOR. OR MIXED PARENTAGE	757	YEARS OF SCHOOL COMPLETED	
UNITED KINGDOM	40	PERSONS 25 YEARS OLD AND OVER	3 233
IRELAND (EIRE)	31	NO SCHOOL YEARS COMPLETED	21
NORWAY	29	ELEMENTARY: 1 TO 4 YEARS	167
SWEDEN	11	5 TO 7 YEARS	313
GERMANY	427	8 YEARS	277
POLAND	116	HIGH SCHOOL: 1 TO 3 YEARS	702
CZECHOSLOVAKIA	28	4 YEARS	757
AUSTRIA	59	COLLEGE: 1 TO 3 YEARS	227
HUNGARY	76	4 YEARS OR MORE	291
U.S.S.R.	17	MEDIAN SCHOOL YEARS COMPLETED	NSC:0.6
ITALY	222		
CANADA	27	*RESIDENCE IN 1955*	
MEXICO	4	PERSONS 5 YEARS OLD AND OVER: 1955	4 610
ALL OTHER AND NOT REPORTED	157	SAME HOUSE AS IN 1950	2 976
		DIFFERENT HOUSE IN U.S.	1 554
HOUSEHOLD RELATIONSHIP		CENTRAL CITY OF THIS SMSA	1 204
POPULATION IN HOUSEHOLDS	4 917	OTHER PART OF THIS SMSA	189
HEAD OF HOUSEHOLD	1 672	OUTSIDE THIS SMSA	142
HEAD OF PRIMARY FAMILY	1 364	NORTH AND WEST	109
PRIMARY INDIVIDUAL	268	SOUTH	54
WIFE OF HEAD	1 164	ARRANGED	72
CHILD UNDER 18 OF HEAD	1 194	MOVED: RESIDENCE IN 1955 NOT REPORTED	54
OTHER RELATIVE OF HEAD	824		
NONRELATIVE OF HEAD	90	*FAMILY INCOME IN 1959*	
POPULATION IN GROUP QUARTERS	30	ALL FAMILIES	1 407
INMATE OF INSTITUTION	1	UNDER \$1,000	20
OTHER	30	\$1,000 TO \$14,999	25
POPULATION PER HOUSEHOLD	3.01	\$15,000 TO \$24,999	65
		\$25,000 TO \$34,999	95
MARRIED COUPLES	1 260	\$35,000 TO \$44,999	79
WITH OWN HOUSEHOLD	1 222	\$45,000 TO \$54,999	231
WITH OWN CHILDREN UNDER 18	251	\$55,000 TO \$64,999	182
WITH OWN CHILDREN UNDER 18	594	\$65,000 TO \$74,999	193
WITH HUSBAND UNDER 45	500	\$75,000 TO \$84,999	161
WITH OWN CHILDREN UNDER 18	398	\$85,000 TO \$94,999	106
UNRELATED INDIVIDUALS	342	\$95,000 TO \$14,999	212
		\$15,000 TO \$24,999	70
PERSONS UNDER 18 YEARS OLD	1 315	\$25,000 AND OVER	8
LIVING WITH BOTH PARENTS	1 152	*MEDIAN INCOME: FAMILIES	NSC:0.42
		FAM. & UNREL. INDIV.	54 349

NOT REPRODUCIBLE

Census Table P-1. General Characteristics of the
Population by Census Tracts: 1960-Con.

(Median not shown where base is less than 50)

SUBJECT		TRACT 0001		SUBJECT		TRACT 0001	
		MALE	FEMALE			MALE	FEMALE
AGE							
TOTAL.		2 316	2 631	WHITE.	2 167	2 496	
UNDER 5 YEARS.		40	34	UNDER 5 YEARS.	164	159	
1 YEAR.		30	39	5 TO 9 YEARS.	164	172	
2 YEARS.		38	26	10 TO 14 YEARS.	190	187	
3 YEARS.		36	32	15 TO 19 YEARS.	172	157	
4 YEARS.		32	30	20 TO 24 YEARS.	113	124	
5 YEARS.		36	41	25 TO 29 YEARS.	101	84	
6 YEARS.		34	31	30 TO 34 YEARS.	102	134	
7 YEARS.		45	36	35 TO 39 YEARS.	147	167	
8 YEARS.		24	40	40 TO 44 YEARS.	160	184	
9 YEARS.		32	38	45 TO 49 YEARS.	153	181	
10 YEARS.		34	35	50 TO 54 YEARS.	173	203	
11 YEARS.		39	29	55 TO 59 YEARS.	152	184	
12 YEARS.		42	41	60 TO 64 YEARS.	129	175	
13 YEARS.		40	49	65 TO 69 YEARS.	94	138	
14 YEARS.		47	37	70 TO 74 YEARS.	79	116	
15 YEARS.		38	35	75 YEARS AND OVER.	74	123	
16 YEARS.		46	46	MEDIAN AGE.	37.6	41.7	
17 YEARS.		40	28	NONWHITE.	149	137	
18 YEARS.		25	31	UNDER 5 YEARS.	12	2	
19 YEARS.		32	25	5 TO 9 YEARS.	7	6	
20 YEARS.		25	29	10 TO 14 YEARS.	12	7	
21 YEARS AND OVER.		1 961	1 896	15 TO 19 YEARS.	9	8	
				20 TO 24 YEARS.	7	10	
				25 TO 29 YEARS.	11	6	
				30 TO 34 YEARS.	10	14	
				35 TO 39 YEARS.	4	7	
				40 TO 44 YEARS.	11	7	
				45 TO 49 YEARS.	7	6	
				50 TO 54 YEARS.	13	15	
				55 TO 59 YEARS.	13	17	
				60 TO 64 YEARS.	12	7	
				65 TO 69 YEARS.	11	8	
				70 TO 74 YEARS.	5	9	
				75 YEARS AND OVER.	5	6	
				MEDIAN AGE.	41.1	44.8	
TOTAL.		2 316	2 631	MARITAL STATUS			
UNDER 5 YEARS.		171	161	TOTAL: 14 YEARS AND OVER.	1 814	2 127	
5 TO 9 YEARS.		171	186	SINGLE.	417	499	
10 TO 14 YEARS.		202	194	MARRIED.	1 392	1 291	
15 TO 19 YEARS.		181	165	SEPARATED.	17	37	
20 TO 24 YEARS.		127	134	WIDOWED.	79	341	
25 TO 29 YEARS.		112	90	DIVORCED.	16	56	
30 TO 34 YEARS.		112	148	NONWHITE: 14 YEARS AND OVER	123	123	
35 TO 39 YEARS.		151	169	SINGLE.	27	24	
40 TO 44 YEARS.		171	191	MARRIED.	91	82	
45 TO 49 YEARS.		160	187	SEPARATED.	2	1	
50 TO 54 YEARS.		186	218	WIDOWED.	5	16	
55 TO 59 YEARS.		165	206	DIVORCED.	...	3	
60 TO 64 YEARS.		141	182				
65 TO 69 YEARS.		105	146				
70 TO 74 YEARS.		84	125				
75 TO 79 YEARS.		45	77				
80 TO 84 YEARS.		23	37				
85 YEARS AND OVER.		11	15				
MEDIAN AGE.		AGE 37.6	41.8				

NOT REPRODUCIBLE

Census Table P-2. Age, Color, and Marital Status of the Population, by Sex, By Census Tracts: 1960-Con.

(Based on 25-percent sample. Percent not shown where base is less than 200)

SUBJECT		TRACT 0001	SUBJECT	TRACT 0001
EMPLOYMENT STATUS, OCC., & INDUSTRY				
MALE, 14 YEARS OLD AND OVER, . . .		1 814	TOTAL EMPLOYED	2 304
LABOR FORCE		1 486	MINING	...
PERCENT OF TOTAL		81.9	CONSTRUCTION	144
WKR	CIVILIAN LABOR FORCE	1 482	MANUFACTURING	590
UEM	EMPLOYED	1 458	FURNITURE & LUMBER & WOOD PRODUCTS	...
	UNEMPLOYED	24	METAL INDUSTRIES	111
	PERCENT OF CIV. LABOR FORCE	1.6	MACHINERY	77
	NOT IN LABOR FORCE	328	TRANSPORTATION EQUIPMENT	78
	FEMALE, 14 YEARS OLD AND OVER, . . .	2 127	OTHER DURABLE GOODS	19
LABOR FORCE		858	FOOD AND KINDRED PRODUCTS	99
PERCENT OF TOTAL		40.3	TEXTILE AND APPAREL PRODUCTS	34
WKR	CIVILIAN LABOR FORCE	846	PRINT., PUBLISHING, & ALLIED INDUS.	57
UEM	EMPLOYED	812	OTHER NONDUP. (INCL. NOT SPEC. MFG.)	65
	UNEMPLOYED	12	RAILROAD AND RAILWAY EXPRESS SERVICE	56
	PERCENT OF CIV. LABOR FORCE	1.4	OTHER TRANSPORTATION	72
	NOT IN LABOR FORCE	1 240	COMMUN., UTIL., & SANITARY SERV.	169
	MARRIED WOMEN IN L.F., HUSBAND PRES. . .	427	WHOLESALE TRADE	61
	WITH OWN CHILDREN UNDER 6	43	EATING AND DRINKING PLACES	29
	MALE, EMPLOYED	1 458	OTHER RETAIL TRADE	312
SAL	PROFESS., TECH., & KINDRED WORKERS . . .	229	BUSINESS AND REPAIR SERVICES	43
CLK	MGRS., OFFS., & PROPRI., INCL. FARM. . .	174	PRIVATE HOUSEHOLDS	8
SKL	CLERICAL AND KINDRED WORKERS	209	OTHER PERSONAL SERVICES	93
SSK	SALES WORKERS	121	HOSPITALS	55
USK	CRAFTSMEN, FOREMEN, & KINDRED WORKERS .	339	EDUCATIONAL SERVICES	125
	OPERATIVES AND KINDRED WORKERS	187	OTHER PROFESSIONAL AND RELATED SERV. . .	129
	PRIVATE HOUSEHOLD WORKERS	...	PUBLIC ADMINISTRATION	232
	SERVICE WKS., EXC. PRIV. HOUSEHOLD. . .	103	OTHER INDUSTRIES (INCL. NOT REPORTED) . .	236
	LABORERS, EXCEPT MINE	26	MEANS OF TRANSPORT, & PLACE OF WORK	
	OCCUPATION NOT REPORTED	72	ALL WORKERS (INCL. ARMED FORCES) . . .	2 261
	FEMALE, EMPLOYED	896	PRIVATE AUTOMOBILE OR CAR POOL	1 428
SAL	PROFESS., TECH., & KINDRED WORKERS . . .	129	RAILROAD	4
CLK	MGRS., OFFS., & PROPRI., INCL. FARM. . .	58	SUBWAY OR ELEVATED	...
SKL	CLERICAL AND KINDRED WORKERS	371	BUS OR STREETCAR	318
SSK	SALES WORKERS	97	WALKED TO WORK	120
USK	CRAFTSMEN, FOREMEN, & KINDRED WORKERS .	24	OTHER MEANS	29
	OPERATIVES AND KINDRED WORKERS	62	WORKED AT HOME	83
	PRIVATE HOUSEHOLD WORKERS	...	NOT REPORTED	79
	SERVICE WKS., EXC. PRIV. HOUSEHOLD. . .	60	INSIDE SMSA	125
	LABORERS, EXCEPT MINE	...	BALTIMORE CITY	1 896
	OCCUPATION NOT REPORTED	41	ANNE ARUNDEL COUNTY	22
TOTAL EMPLOYED		2 304	BALTIMORE COUNTY	204
PRIVATE WAGE AND SALARY WORKERS		1 703	CARROLL COUNTY	3
GOVERNMENT WORKERS		382	HOWARD COUNTY	...
SELF-EMPLOYED WORKERS		198	OUTSIDE SMSA	49
UNPAID FAMILY WORKERS		21	PLACE OF WORK NOT REPORTED	87

NOT REPRODUCIBLE

Census Table P-3. Labor Force Characteristics of the Population by Census Tracts: 1960-

(Some data based on sample; see text. Median not shown where base is less than 70)

SUBJECT	TRACT 0001	SUBJECT	TRACT 0001
ALL HOUSING UNITS.	ALL 1 685	1. UNITS IN STRUCTURE	SFH 1 048
TENURE, COLOR, AND VACANCY STATUS		2.	493
OWNER OCCUPIED	OWN 231	3 AND 4.	28
WHITE.	1 127	5 TO 9	10
NONWHITE.	104	10 OR MORE	...
RENTER OCCUPIED.	454	YEAR STRUCTURE BUILT	NEW 115
WHITE.	399	1950 TO MARCH 1960	107
NONWHITE.	2	1940 TO 1949	323
AVAILABLE VACANT	VAC 36	1939 OR EARLIER.	...
FOR SALE ONLY.	10	BASEMENT	BMT 1 160
FOR RENT	26	CONCRETE SLAB.	15
OTHER VACANT	17	OTHER.	10
CONDITION AND PLUMBING		HEATING EQUIPMENT	
SOUND.	SND 1 641	STEAM OR HOT WATER.	1 346
WITH ALL PLUMBING FACILITIES	625	BURN AIR FURNACE	114
LACKING ONLY HOT WATER	1	BUILT-IN ROOM UNITS.	20
LACKING OTHER PLUMBING FACILITIES.	5	OTHER MEANS WITH FLUE.	3
DETERIORATING.	43	OTHER MEANS WITHOUT FLUE	8
WITH ALL PLUMBING FACILITIES	41	NONE	...
LACKING ONLY HOT WATER	...	ALL OCCUPIED UNITS	1 632
LACKING OTHER PLUMBING FACILITIES.	2	PERSONS	
DILAPIDATED.	DLP 1	1 PERSON.	249
BATHROOMS		2 PERSONS.	553
1.	BTH 1 130	3 PERSONS.	130
MORE THAN 1.	53	4 PERSONS.	229
SHARED OR NONE	6	5 PERSONS.	121
ROOMS		6 PERSONS OR MORE.	50
1 ROOM.	4	MEDIAN	
2 ROOMS.	12	ALL OCCUPIED	1.5
3 ROOMS.	191	OWNER.	2.0
4 ROOMS.	237	RENTER.	2.2
5 ROOMS.	277	PERSONS PER ROOM	
6 ROOMS.	412	0.50 OR LESS	994
7 ROOMS.	247	0.51 TO 0.75	409
8 ROOMS OR MORE.	255	0.76 TO 1.00	219
MEDIAN	MRN 5.8	1.01 OR MORE	50

Table H-2.—YEAR MOVED INTO UNIT, AUTOMOBILES AVAILABLE, AND VALUE OR RENT OF OCCUPIED HOUSING UNITS, BY CENSUS TRACTS: 1960—Con.

(Some data based on sample; median not shown where base is insufficient; see text.
Plus (+) or minus (−) after number indicates median above or below that number)

SUBJECT	TRACT 0001	SUBJECT	TRACT 0001
ALL OCCUPIED UNITS	1 632	\$20,000 TO \$24,999	47
YEAR MOVED INTO UNIT		\$25,000 OR MORE.	12
1959 TO MARCH 1960	MVD 364	MEDIAN DOLLARS	MPV 12 600
1954 TO 1957	311	GROSS RENT	
1950 TO 1953	580	RENTER OCCUPIED.	461
1939 OR EARLIER.	377	LESS THAN \$20.	...
AUTOMOBILES AVAILABLE		\$20 TO \$39	...
1.	967	\$40 TO \$59	29
2.	283	\$60 TO \$79	184
3 OR MORE.	21	\$80 TO \$99	98
NONE	CAR 361	\$100 TO \$149	94
VALUE		\$150 OR MORE	4
OWNER OCCUPIED	1 021	NO CASH RENT	32
LESS THAN \$5,000	1	MEDIAN DOLLARS	MGR 77
\$5,000 TO \$9,999	177	CONTRACT RENT	
\$10,000 TO \$14,999	646	RENTER OCCUPIED.	369
\$15,000 TO \$19,999	138	MEDIAN DOLLARS	MCR 73

NOT REPRODUCIBLE

Census Table H-1. Occupancy and Structural Characteristics of Housing Units, by Census Tracts: 1960—Con.

(Some data based on sample, median not shown where base is insufficient; no unit. Plus (+) or minus (-) after number indicates median above or below that number)

SUBJECT	TOTAL SMSA ¹	BACH- INSTON: D.C.	MONTGOMERY COUNTY, MD.					PRINCE GEORGES COUNTY, MD.	ARLINGTON COUNTY, VA.	FAIRFAX COUNTY, VA. ²	
			TOTAL	BETHESDA (U)	ROCKVILLE	SILVER SPRINGS (U)	WHEATON (U)				BALANCE
ALL OCCUPIED UNITS	592 223	252 066	92 433	15 980	6 315	19 792	13 117	37 329	94 945	54 498	69 847
YEAR MOVED INTO UNIT											
1958 TO MARCH 1959	234 236	98 733	32 578	5 979	2 349	6 942	4 507	13 041	36 722	26 543	28 899
1954 TO 1957	169 127	70 310	28 055	5 175	2 155	5 143	4 745	10 872	27 070	14 293	20 912
1940 TO 1953	144 459	60 957	24 442	3 976	1 550	7 012	3 724	10 172	25 577	13 225	17 037
1939 OR EARLIER	40 819	21 976	5 342	839	208	975	126	3 184	5 624	3 470	2 317
AUTOMOBILES AVAILABLE											
1	322 175	110 040	53 654	8 543	3 618	12 368	8 243	---	41 342	34 131	40 496
2	106 176	18 643	30 043	5 915	1 843	5 336	4 432	---	21 771	9 844	19 459
3 OR MORE	13 945	4 071	3 635	689	378	764	259	---	2 776	1 105	1 795
NONE	148 281	119 262	5 049	833	519	1 104	192	---	8 082	7 418	2 796
VALUE											
OWNER OCCUPIED	276 045	71 306	45 433	11 973	4 704	12 535	11 850	28 342	36 737	21 773	46 361
LESS THAN \$5,000	3 543	356	456	---	25	27	28	376	1 792	47	733
\$5,000 TO \$9,999	15 934	5 872	1 835	8	201	86	154	985	4 484	767	1 059
\$10,000 TO \$14,999	77 179	27 235	10 759	250	2 306	1 504	3 717	2 978	21 223	4 512	9 659
\$15,000 TO \$19,999	84 635	19 356	21 124	1 974	1 737	3 394	5 537	6 412	19 254	7 354	14 735
\$20,000 TO \$24,999	44 008	7 269	13 478	2 721	308	3 649	1 974	6 635	6 259	4 442	10 027
\$25,000 TO \$29,999	42 765	11 193	18 176	7 020	131	1 653	390	8 732	3 236	4 433	9 618
\$30,000 OR MORE	17 100	15 402	19 820	27 430	14 700	19 300	16 700	31 530	15 100	18 800	18 700
MEDIAN DOLLARS											
GROSS RENT											
RENTER OCCUPIED	300 534	176 534	26 320	3 954	1 571	7 174	1 203	10 425	33 729	31 905	15 232
LESS THAN \$20	381	208	80	11	---	8	13	48	53	11	17
\$20 TO \$29	5 933	4 876	237	8	24	20	17	172	407	78	129
\$30 TO \$39	24 427	20 335	899	42	82	31	19	709	1 443	307	497
\$40 TO \$49	73 659	57 031	2 705	210	214	525	34	1 705	4 204	8 320	1 917
\$50 TO \$59	93 522	50 179	6 016	1 016	380	1 659	124	2 674	13 054	10 812	3 735
\$60 TO \$69	70 165	29 825	8 817	1 343	655	3 293	373	2 453	9 659	11 931	4 939
\$70 TO \$79	25 919	10 713	4 246	1 215	140	1 290	356	1 245	1 736	3 398	3 254
\$80 OR MORE	7 425	3 347	1 324	109	76	121	97	975	1 141	378	877
NO CASH RENT	88	81	107	119	103	113	129	96	91	100	107
MEDIAN DOLLARS											
CONTRACT RENT											
RENTER OCCUPIED	293 039	173 137	23 001	3 845	1 455	7 055	1 154	9 450	32 389	31 507	14 355
MEDIAN DOLLARS	82	75	98	114	87	106	103	89	65	96	98

SUBJECT	ALEX- ANDRIA, VA.	FALLS CHURCH, VA.	WASHINGTON, D.C.								
			TRACT 0001	TRACT 0002	TRACT 0003	TRACT 0004	TRACT 0005	TRACT 0006	TRACT 0007	TRACT 0008	TRACT 0009
ALL OCCUPIED UNITS	28 972	2 812	2 785	1 555	2 509	342	3 728	2 213	6 741	2 190	1 835
YEAR MOVED INTO UNIT											
1958 TO MARCH 1959	13 681	1 080	1 140	808	858	90	1 262	699	1 800	849	452
1954 TO 1957	7 546	794	684	266	373	57	1 042	464	1 760	336	447
1940 TO 1953	5 414	829	441	372	417	129	859	713	931	433	667
1939 OR EARLIER	1 931	109	320	169	431	66	373	335	240	302	243
AUTOMOBILES AVAILABLE											
1	18 274	---	1 521	817	1 613	190	1 475	1 043	2 741	1 175	947
2	4 327	---	269	173	246	105	326	215	374	541	433
3 OR MORE	629	---	70	91	35	36	78	66	41	90	113
NONE	5 350	---	925	476	615	31	1 829	619	1 939	346	142
VALUE											
OWNER OCCUPIED	10 232	1 724	835	576	1 071	290	556	1 081	788	1 199	1 301
LESS THAN \$5,000	45	4	1	---	---	---	---	---	2	1	---
\$5,000 TO \$9,999	847	25	8	3	8	---	---	---	33	8	11
\$10,000 TO \$14,999	3 468	323	20	13	127	---	---	21	55	148	123
\$15,000 TO \$19,999	2 134	428	42	43	725	3	95	91	233	186	227
\$20,000 TO \$24,999	1 970	354	76	79	157	12	130	246	162	223	157
\$25,000 TO \$29,999	1 735	372	690	438	54	275	309	450	235	408	1 053
\$30,000 OR MORE	16 500	19 100	25 000	25 000	17 800	25 000	25 000	25 273	20 100	25 000	25 000
MEDIAN DOLLARS											
GROSS RENT											
RENTER OCCUPIED	17 745	1 062	1 834	952	1 424	71	3 145	1 033	3 645	976	317
LESS THAN \$20	12	---	---	---	6	---	16	8	13	---	---
\$20 TO \$29	227	12	8	16	4	---	35	19	16	---	---
\$30 TO \$39	755	19	12	31	12	---	49	39	83	16	10
\$40 TO \$49	3 795	104	235	123	212	6	711	191	334	109	29
\$50 TO \$59	4 453	175	319	120	564	8	741	288	1 140	269	49
\$60 TO \$69	8 427	510	617	276	356	---	1 050	242	1 140	153	127
\$70 TO \$79	1 741	122	421	337	216	48	876	231	916	399	121
\$80 OR MORE	330	21	39	39	44	31	47	65	43	32	14
NO CASH RENT	49	111	126	137	96	---	115	95	111	126	131
MEDIAN DOLLARS											
CONTRACT RENT											
RENTER OCCUPIED	17 430	1 041	1 808	913	1 375	85	3 044	1 018	3 315	942	313
MEDIAN DOLLARS	45	97	119	124	92	---	113	89	129	120	122

¹ COMPLETE-HOUST DATA HAVE NOT BEEN ADJUSTED FOR REVISIONS MADE IN TRACT FAX-27.

Census Table H-2. Year Moved into Unit, Automobiles Available, and Value or Rent of Occupied Housing Units, by Census Tracts: 1960.

(Some data based on sample; median not shown where base is insufficient; see text. Plus (+) or minus (-) after number indicates median above or below that number)

SUBJECT	WASHINGTON, D.C.--CON.										
	TRACT 0010	TRACT 0011	TRACT 0012	TRACT 0013	TRACT 0014	TRACT 0015	TRACT 0016	TRACT 0017	TRACT 0018	TRACT 0019	TRACT 0020
ALL OCCUPIED UNITS	5 220	1 709	2 131	3 906	2 338	1 858	1 572	2 096	3 480	2 454	2 475
YEAR MOVED INTO UNIT											
1958 TO MARCH 1959	1 751	891	837	1 399	507	312	311	708	1 590	875	840
1954 TO 1957	1 287	512	454	1 177	812	353	343	889	1 006	782	714
1940 TO 1953	1 517	583	510	1 142	760	790	618	578	710	632	734
1939 OR EARLIER	605	323	330	188	459	391	300	271	174	400	277
AUTOMOBILES AVAILABLE											
1	2 871	1 023	1 240	1 856	1 305	1 016	662	1 105	1 944	1 406	1 221
2	652	309	287	845	434	704	433	228	320	394	348
3 OR MORE	40	15	40	86	30	44	126	32	76	34	47
NONE	1 617	362	364	1 509	569	72	131	681	1 140	603	859
VALUE											
OWNER OCCUPIED	2 027	1 032	858	761	1 388	1 499	1 377	967	765	1 893	1 071
LESS THAN \$5,000	...	...	...	...	...	...	...	...	...	...	...
\$5,000 TO \$9,999	3	4	3	7	...	3	...	17	7	30	11
\$10,000 TO \$14,999	88	86	25	26	37	28	22	352	62	791	237
\$15,000 TO \$19,999	463	298	223	93	285	132	143	454	362	907	512
\$20,000 TO \$24,999	665	273	278	76	588	448	324	103	235	124	171
\$25,000 OR MORE	808	371	329	539	878	1 058	848	31	79	20	120
MEDIAN DOLLARS	23 500	22 300	23 200	25 000+	23 200	23 000+	23 000+	16 200	19 300	15 600	17 600
GROSS RENT											
RENTER OCCUPIED	3 158	824	1 273	3 137	923	167	228	916	2 677	534	1 331
LESS THAN \$20	12	...	4	8	...	...	...	...	8	...	...
\$20 TO \$39	17	4	17	2	8	3	...	8	12	8	28
\$40 TO \$59	1 048	18	18	8	...	...	...	46	45	9	58
\$60 TO \$79	92	18	49	64	73	...	...	272	493	159	422
\$80 TO \$99	518	70	312	1 097	213	...	...	35	307	936	114
\$100 TO \$149	1 010	206	328	1 126	332	8	34	154	772	190	276
\$150 OR MORE	318	285	523	778	284	134	34	88	332	43	67
NO CASH RENT	45	33	24	30	8	22	21	41	39	15	58
MEDIAN DOLLARS	89	147	137	120	129	...	93	85	94	93	85
CONTRACT RENT											
RENTER OCCUPIED	3 113	591	1 249	3 087	915	169	207	875	2 818	519	1 273
MEDIAN DOLLARS	88	137	129	120	127	...	79	80	92	82	79
SUBJECT	WASHINGTON, D.C.--CON.										
	TRACT 0021	TRACT 0022	TRACT 0023- 001	TRACT 0023- 002	TRACT 0024	TRACT 0025	TRACT 0026	TRACT 0027	TRACT 0028	TRACT 0029	TRACT 0030
ALL OCCUPIED UNITS	4 338	2 761	1 215	22	1 463	2 892	877	4 844	3 187	1 911	1 673
YEAR MOVED INTO UNIT											
1958 TO MARCH 1959	1 597	904	264	13	309	980	189	1 925	1 355	824	819
1954 TO 1957	1 652	954	402	...	408	850	267	1 394	940	539	419
1940 TO 1953	824	642	435	3	438	842	342	1 085	609	472	299
1939 OR EARLIER	435	261	114	8	88	190	99	440	243	72	107
AUTOMOBILES AVAILABLE											
1	2 324	1 356	601	13	709	1 399	554	1 768	825	645	424
2	358	265	143	5	70	204	166	274	65	65	31
3 OR MORE	42	16	5	...	21	87	35	89	70	17	10
NONE	1 612	1 091	466	4	663	1 242	142	2 713	2 226	1 186	1 228
VALUE											
OWNER OCCUPIED	1 947	1 501	643	...	737	1 115	610	986	349	486	212
LESS THAN \$5,000	6	...	7	...	...	...	...	...	4	...	2
\$5,000 TO \$9,999	71	108	24	...	22	19	...	35	32	25	10
\$10,000 TO \$14,999	899	781	333	...	419	432	10	423	194	327	87
\$15,000 TO \$19,999	865	374	242	...	289	576	70	829	97	123	97
\$20,000 TO \$24,999	90	22	6	...	17	74	137	45	11	8	12
\$25,000 OR MORE	16	16	1	...	8	18	392	55	11	3	4
MEDIAN DOLLARS	15 000	14 100	13 900	...	16 200	16 000	23 000+	15 400	15 600	13 300	15 400
GROSS RENT											
RENTER OCCUPIED	2 362	1 183	498	22	691	1 701	281	3 775	2 816	1 340	1 416
LESS THAN \$20	...	...	...	...	...	...	...	...	...	...	...
\$20 TO \$39	4	3	7	...	8	5	...	94	42	20	53
\$40 TO \$59	76	55	43	4	74	101	...	273	353	374	333
\$60 TO \$79	632	308	115	...	222	550	4	903	933	567	423
\$80 TO \$99	792	459	154	...	174	698	67	1 373	900	352	273
\$100 TO \$149	539	246	123	...	167	253	115	784	365	158	73
\$150 OR MORE	82	53	29	...	34	64	84	261	45	11	17
NO CASH RENT	37	53	20	...	12	30	24	85	72	48	16
MEDIAN DOLLARS	85	63	49	...	83	85	131	93	60	75	68
CONTRACT RENT											
RENTER OCCUPIED	2 225	1 150	473	4	679	1 671	257	3 632	2 704	1 312	1 400
MEDIAN DOLLARS	79	50	78	...	77	78	150	87	74	72	64

Census Table H-2. Year Moved into Unit, Automobiles Available, and Value or Rent of Occupied Housing Units, by Census Tracts: 1960. (Continued)

3.0 NTIS MAGNETIC TAPES

The National Technical Information Service (NTIS) of the Department of Commerce offers magnetic tapes containing information pertinent to various business and scientific fields of interest. Most ^{Tapes} types are in BCD mode and are available as: (1) 7-track, 556 or 800 characters per inch (cpi), odd or even parity; or (2) 9-track, 800 cpi, odd parity. Included in this series are tapes containing information from the censuses of population and housing.

Information is given in a format that lists each item of information together with its location. Information includes family relationship within a household, school enrollment of children, income, employment status, number of personnel employed by industry and in agriculture, tenancy and vacancy status of housing units, value of property, heating fuels used, and numbers of workers classified according to type of work. Tapes currently available are listed in Table B.3-1.

Table B.3-1

List of NTIS Tapes of Population and Housing Data
(1960 for the United States by Standard Location Area)

- PB-170 771 -- Population and Housing Data for the United States by Standard Location Areas, 1960 Census: Hawaii, Vermont, Idaho, Nebraska, Arkansas, Delaware, Rhode Island, South Dakota, Montana, Colorado, 1 reel.
- PB-170 772 -- Same Title, Louisiana, North Carolina, Indiana, 1 reel.
- PB-170 773 -- Same Title, Minnesota, Mississippi, South Carolina, Oklahoma, District of Columbia, 1 reel.
- PB-170-774 -- Same Title, Ohio, 1 reel.
- PB-170-775 -- Same Title, Nevada, Washington, 1 reel.
- PB-170-776 -- Same Title, Michigan, Wisconsin, 1 reel
- PB-170-777 -- Same Title, Pennsylvania, 1 reel.
- PB-170-778 -- Same Title, Alaska, West Virginia, Oregon, Alabama, Florida, 1 reel.
- PB-170-779 -- Same Title Iowa, Maryland, Kansas, Maine, North Dakota, New Mexico, Wyoming, 1 reel.
- PB-170-780 -- Same Title, Texas, Connecticut, 1 reel.
- PB-170-781 -- Same Title, Virginia, Tennessee, Kentucky, Arizona, 1 reel.
- PB-170-782 -- Same Title, Missouri, Utah, New Hampshire, New Jersey, 1 reel.
- PB-170-783 -- Same Title, Georgia, Massachusetts, 1 reel.
- PB-170-784 -- Same Title, Illinois, 1 reel.
- PB-170-785 -- Same Title, New York, Part I, 1 reel.
- PB-170-786 -- Same Title, California, Part I, 1 reel.
- PB-170-787 -- Same Title, New York, Part II, California, Part II, 1 reel.

BLANK PAGE

APPENDIX C
PRO FORMA DAMAGE FUNCTION DEVELOPMENT^{*}

1.0 INTRODUCTION

Linear relations have been developed by the Office of Air Programs for predicting the multiple effects of specific pollutants (sulfur dioxides and particulates). These damage functions are based on the estimates computed by Barrett and Waddell in "The Cost of Air Pollution Damages: A Status Report"^{**}. This study reviewed approximately 36 research studies of air pollution damages that were in various stages of completion. About a third of the studies have been published, another third completed and unpublished and a third in progress.

The Barrett-Waddell survey estimated annual national air pollution damages (1968) due to the pollutants: sulfur dioxide, particulates, photochemical oxidants and nitrogen oxides. Particulates and sulfur dioxide account for 88 percent of the total damage.

Four major damage categories were analyzed, and damage cost estimates were determined for each category. These were: (1) residential property; (2) materials; (3) health; and, (4) vegetation.

The sources of the pollutants included: stationary fuel combustion, transportation, industrial processes, solid waste disposal and miscellaneous sources. The damages attributed to each source category were also reported.

^{*} Taken from: A Pro Forma Air Pollution Damage Function, Environmental Protection Agency, Office of Air Programs, (Unpublished Paper).

^{**} HEW, NAPCA, Raleigh, North Carolina, (Unpublished Paper).

Descriptions of the points are as follows:

$(C_1)_1$ = Per capita cost of effects for pollutant, 1, in 1968.

$(C_1)_2$ = Per capita cost of effects of pollutants from miscellaneous, uncontrollable sources (i.e., background concentrations) for pollutant, 1.

$(X_1)_1$ = Average annual urban concentration of pollutant, 1, considered to be a background level.

$(X_1)_2$ = Average annual concentration of pollutant, 1, found in the nation's urban areas in 1968.

The development of the four coordinates, C_1 , C_2 , X_1 , X_2 , are dependent upon the following general data inputs:

(1) Urban Population--the U. S. Urban population for 1968.

(2) Damage Cost Estimates

A. The total national air pollution damage cost estimate for sulfur dioxide and particulate emissions (1968).

B. The total national air pollution damage cost estimate for sulfur dioxide and particulate emissions from miscellaneous sources (i.e., background levels).

(3) Pollution Concentration Estimates

A. The weighted average pollution concentration (sulfur dioxide and particulates) to which the 1968 U. S. urban population was exposed.

B. The background pollutant concentration for sulfur dioxide and particulates.

The specific data gathered for the development of the damage function were as follows:

(1) Urban Population

The "current" definition of urban population was used in determining the statistics for 1968. The "current" definition refers to "all the population residing in urban-fringe areas and in unincorporated places of

2,500 or more.*" In 1960, the urban population was 125,269,000, or, 69.9 percent of the nation's population.

In 1970, 73.5 percent of the nation's population was urban. An urban population of 144,000,000 was determined for 1968 by interpolating between the 1960 and 1970 statistics.

(2) Damage Cost

- A. In the Barrett-Waddell report, the 1968 annual damage costs of particulates and sulfur dioxides are estimated, based on the measured air quality for that year.
- B. Barrett and Waddell report that 9.6 tons/year of particulates and 0.6 tons/year of sulfur dioxides originate from miscellaneous sources (see Table C.2-1). It is assumed that these emissions contribute to the background (i.e., uncontrollable emission) concentrations of pollutants. Thus, 33.9 percent of particulate and 1.8 percent of sulfur dioxide emissions are considered uncontrollable (i.e., emissions generated from construction activities, dust off the street or ground, etc.).

Assuming a direct relationship between quantity of emissions generated and the cost of damages, background damage cost estimates can be determined for particulate and sulfur dioxide emissions, respectively.

(3) Pollution Concentration

- A. The most difficult task in developing the damage function was estimating the weighted average pollution concentration (WAPC) for the nation. The WAPC is the concentration to which the average urban resident is exposed. WAPC is determined by the following formula:

$$(WAPC) = \frac{1}{P_T} \sum_{i=1}^n P_i C_i \quad (1)$$

where:

P_T = total U. S. urban population

P_i = urban population in region i.

C_i = weighted average pollution concentration (WAPC) in region i.

* Department of Commerce, Bureau of the Census, U. S. Census of Population: 1960, Vol. I.

** Analogous to the quantity $\overline{PC}$ defined on a political jurisdiction and regional basis in Chapter 2.

Table C.2-1. Estimates of Nationwide Emissions, 1968*

(10⁶ tons/yr)

	<u>CO</u>	<u>Particulates</u>	<u>SO_x</u>	<u>HC</u>	<u>NO_x</u>
Transportation	63.8	1.2	0.8	16.6	8.
Fuel combustion in Stationary Sources	1.9	8.9	24.4	0.7	10.
Industrial processes	9.7	7.5	7.3	4.6	0.
Solid waste disposal	7.8	1.1	0.1	1.6	0.
Miscellaneous	<u>16.9</u>	<u>9.6</u>	<u>0.6</u>	<u>8.5</u>	<u>1.</u>
Total (1968)	100.1	28.3	33.2	32.0	20.

*Source: Division of Air Quality and Emissions Data, BCS, NAPCA.

Available "population" and "air quality" statistics were used to determine WAPC. However, these data were insufficient to develop WAPC without following additional assumptions:

- (1) Air quality data was not available for all the urban regions in the nation (i.e., for the population of 144 million identified by the 1968 Census). The source of air quality data was a recently published data book, Regional Aerometrics Data Book: Sulfur Dioxides and Particulates by OAP's Division of Air Quality and Emissions Data. In this document, 176 "air sheds" are identified; 31 "air sheds" being designated air quality control regions and the remaining being SMSA's. All of the nation's 235 currently designated SMSA's are included.

A total of 61 "air sheds" had sulfur dioxide concentrations for 1968; 132 "air sheds" had particulate concentrations reported. The population of the 61 and 132 air sheds were 108.7 million and 132.4 million, respectively. Consequently, it was necessary to make the assumption that the air pollutant concentrations reported for the identified air sheds were absolutely identical to the air quality to which the 144 million people in the urban population were exposed (i.e., the data for the 61 SO₂ and 132 particulate air sheds were representative of all urban areas).

- (2) The air quality data reported in the Data Book was not an average pollution concentration for the region. There is no way of knowing where the monitoring sites were located in the air sheds in 1968. Although some air sheds had as

many as seven or eight air quality measurements reported, there was no way of statistically determining the average regional pollution concentration.

The problem of obtaining a representative air quality estimate is illustrated in Figure C.2-2. A cross-sectional slice of a metropolitan area is illustrated. Three hypothetical sampling sites are shown-- S_1 , S_2 , and S_3 . With the Data Book, there is no way of knowing where the sites are located or how representative the measurements are relative to the air quality for the remainder of the region.

The desirable air quality estimate is also represented in Figure C.2-2 as the average regional pollution concentration (ARPC). This estimate is the same as the WAPC, except the estimate is regional rather than national in scope. Naturally, the ARPC will fall somewhere between the maximum regional pollution concentration and the background level.

The assumption was made that the air quality concentration reported in the Data Book was equal to ARPC (i.e., the C_1 indicated above). There were some qualifying conditions. The Data Book reported air quality measurements taken at urban, suburban and rural monitoring stations. Only the urban measurements were used in the analysis. In cases where more than one urban measurement was reported, the arithmetic average of all urban stations was determined to be the ARPC.

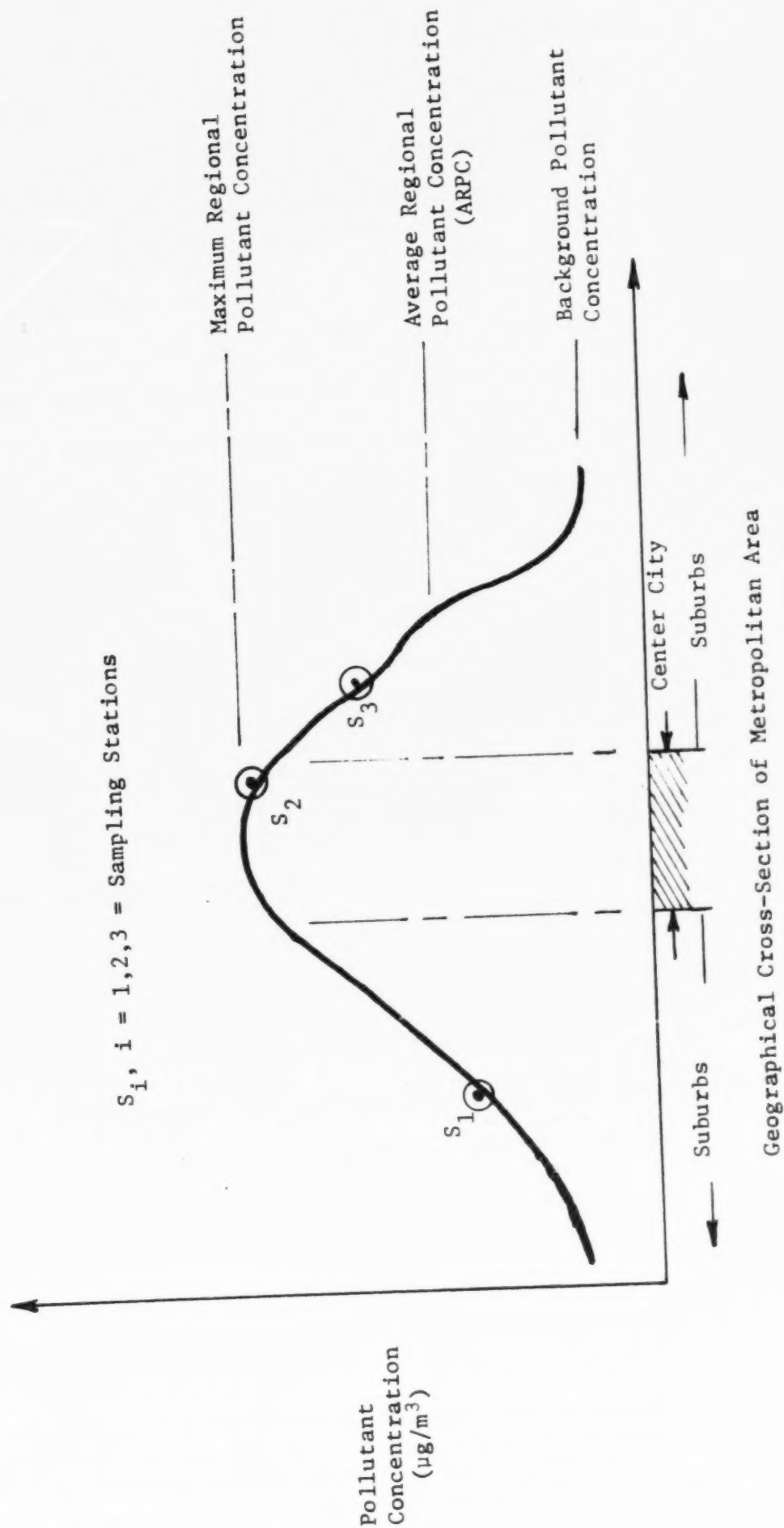


Figure C.2-2. Cross-Section of Metropolitan Area Air Quality

The sulfur dioxide estimates were reported as annual arithmetic averages. Suspended particulates estimates were reported as average geometric averages*. The WAPC was calculated for sulfur dioxide and particulate emissions, using equation (1). The results were:

$$(WAPC)_{SO_x} = 96 \mu\text{g}/\text{m}^3$$

$$(WAPC)_{\text{Part.}} = 97 \mu\text{g}/\text{m}^3$$

It was interesting to compare these results with the direct sum of all ARPC for the 61 and 132 relevant air sheds reporting such data. The averages without weighting were:

$$SO_x = 40.4 \mu\text{g}/\text{m}^3$$

$$\text{Suspended particulates} = 90.5 \mu\text{g}/\text{m}^3.$$

The vast difference between the non-weighted and population-weighted averages results from the existing high concentration of pollutants in the high population regions. ARPC for particulates ranged from 29 to 331 $\mu\text{g}/\text{m}^3$. The ARPC range for sulfur dioxides was 5 to 350 $\mu\text{g}/\text{m}^3$.

Background concentration for sulfur dioxide and particulates were determined from various sources. The calibration procedures of the IPP model predicts a background level. Also, measurements taken on the perimeter of air quality control regions are often considered to be near background levels. The values used in developing the functions were:

$$\text{Sulfur Dioxide Background: } 10 \mu\text{g}/\text{m}^3$$

$$\text{Suspended Particulate Background: } 40 \mu\text{g}/\text{m}^3$$

*Since the standard deviation of the measurements used to determine the annual geometric mean were not available, there was no way of converting the geometric mean to the arithmetic mean. Thus, it was assumed that the geometric mean was equal to the arithmetic mean.

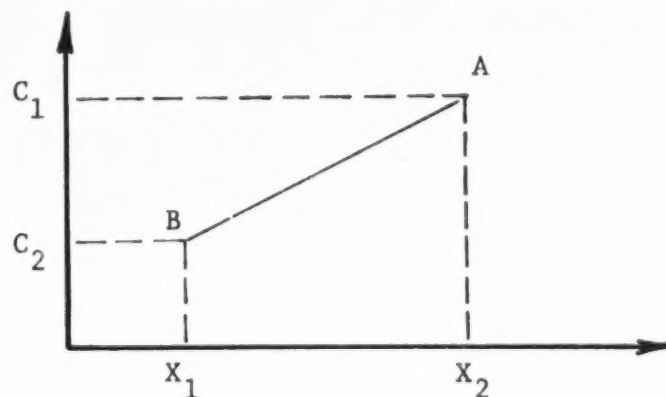
The tentative (pro forma) damage functions that were derived are linear approximations of the damage cost estimates, on a national basis, as related to urban pollution concentrations. It was assumed that all damage costs are realized in the urban areas of the country (as defined by the Bureau of the Census). This is reasonable, since the great majority of the people and economic activity are located in these areas where the pollutant concentrations are the greatest. Vegetation damage was estimated less than one percent of the total annual damage. However, since many of the "urban areas" do include agricultural croplands, this estimate was incorporated into the damage function.

The linear damage functions relate the per capita annual damage cost of each pollutant, sulfur dioxide and particulates (in \$/per capita/year) to pollutant concentration in $\mu\text{g}/\text{m}^3$.

2.0 DEVELOPMENT OF THE NATIONAL DAMAGE FUNCTION

In general, the linear damage function is determined by two points, A and B. Point A represents the average per capita damage cost to the urban residents exposed to the 1968 pollution concentration levels of the nation's AQCRs. Point B represents the minimum air pollution damage resulting from miscellaneous sources (construction activities, urban activity, natural sources, etc.).

From this description, it is easy to see that four coordinates are needed to determine the function:



Definition of Linear Damage Function

The data and assumptions thus far reported were inadequate to determine damage functions for suspended particulates and sulfur dioxide. The coordinates for developing the two linear functions are reported in Tables C.2-2 and C.2-3. The National Damage Functions are shown in Figure C.2-3. Due to the tentative character, they are referred to as the Pro Forma Damage Functions. They serve to provide a demonstration of the use of the Damage Module in the Benefits Segment of the RAPA Cost/Benefit Model. Conversely, the RAPA Cost/Benefit Model will serve to test the reasonableness of the present formulation.

Table C.2-2. National Total Annual Costs of Pollution
For Types Of Pollutants and Effects in 1968.

<u>Effects</u>	<u>SO_x</u>	<u>Particulates</u>	<u>Oxidant</u>	<u>NO_x</u>	<u>Total</u>
Residential Property	2,808	2,392	-	-	5,200
Materials	2,202	691	1,127	732	4,752
Health	3,272	2,788	-	-	6,060
Vegetation	<u>13</u>	<u>7</u>	<u>60</u>	<u>40</u>	<u>120</u>
Total	8,295	5,878	1,187	772	16,132

Source: "The Cost of Air Pollution Damages: A Status Report," Barrett, I.B.,
and Waddell, T. E., HEW, NAPCA (unpublished report).

Table C.2-3

Coordinates for Damage Function Development

<u>Variables</u>	<u>Suspended Particulates</u>	<u>Sulfur Dioxide</u>
C_1	\$40.80/capita	\$57.50/capita
C_2	\$13.80/capita	\$ 1.03/capita
X_1	10 $\mu\text{g}/\text{m}^3$	40 $\mu\text{g}/\text{m}^3$
X_2	97 $\mu\text{g}/\text{m}^3$	96 $\mu\text{g}/\text{m}^3$

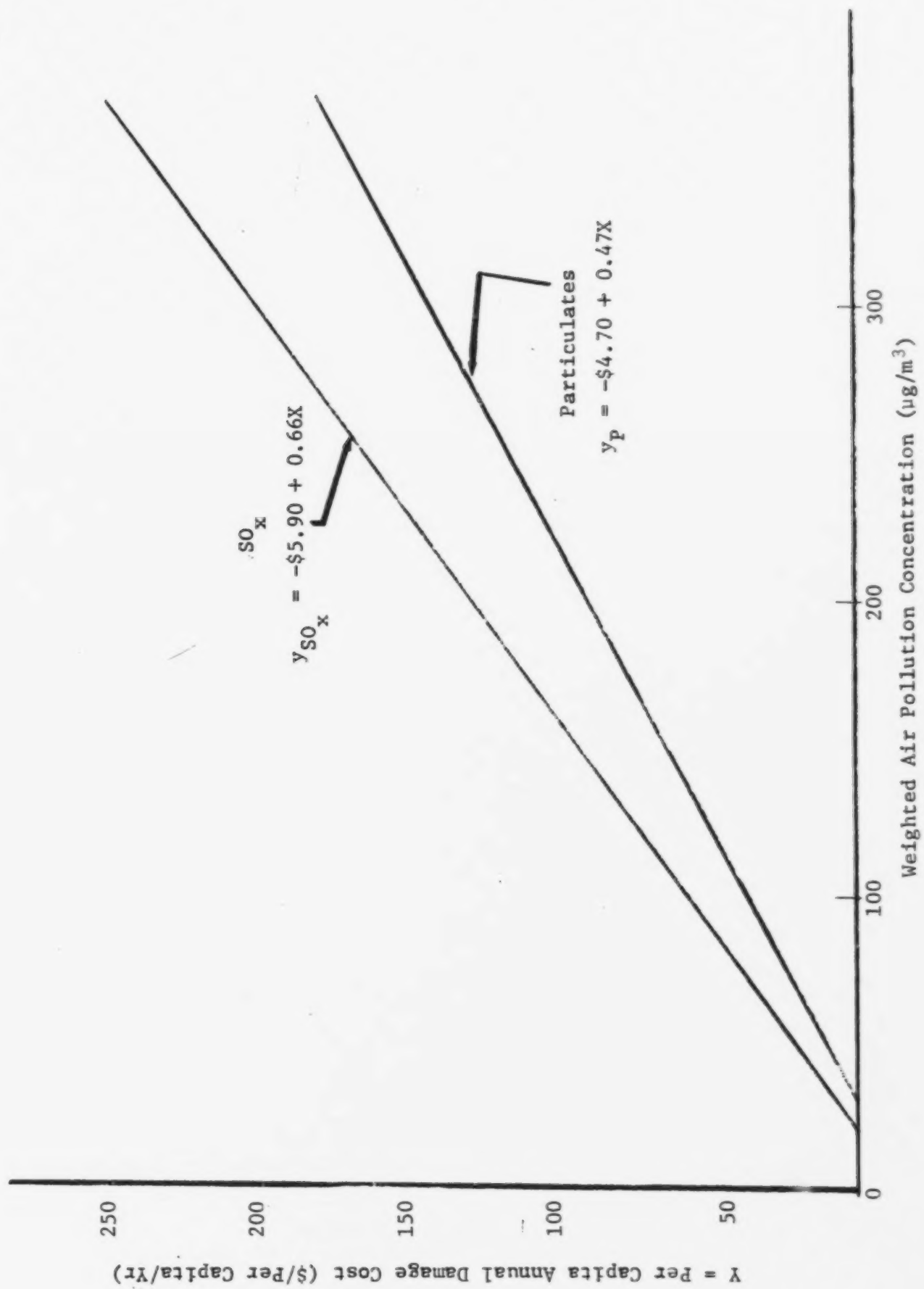


Figure C.2-3. Pro Forma Damage Functions for SO₂ and Particulates

BLANK PAGE

APPENDIX D

DEMONSTRATION RESULTS TO THE POLITICAL JURISDICTION LEVEL

The cost/benefit results of the demonstration at the regional level, along with a description of each of the output variables, is presented in Section 3.0. In this appendix, the results for each of the seven political jurisdictions which make up the NCIAQCR are listed; these results were aggregated to obtain the regional summaries presented in Section 3.0 (and repeated here to make the appendix a complete data package). Tables D.1-1 through D.1-8 present Damage Module output; Tables D.2-1 through D.2-8 present Property Value Module output, and Tables D.3-1 through D.3-8 present Assignment Module output. Interpretation of the various aggregates, averages, etc., presented in these tables should include reference to Sections 2.0 and 3.0 where the various weighting factors used in preparing this output are described. In particular, the cautionary note in Section 3.0 regarding the Assignment Module should be reviewed, i.e., the results are contrary to what is expected and apparently because of an omission in the assignment algorithm.

Average Air Quality						
Strategy	Total Emission (Tons/Day)	Weighted With Respect To Population ($\mu\text{g}/\text{m}^3$)*	Point Emission (Tons/Day)	Damage ($\$ \times 10^6$)	Benefit ($\$ \times 10^6$)	Control Cost ($\$ \times 10^6$)
SO ₂ :						
Existing	660.6	65.0	542.0	73.6	0.0	0.0
S-10	463.4	57.8	344.8	64.0	9.6	-3.5
S-14	332.3	52.8	243.9	57.5	16.1	6.1
S-15	238.0	49.3	176.6	52.9	20.7	14.6
S-11	21.0	36.4	0.0	36.0	37.6,	104.5
Particulates:						
Existing	160.3	69.4	84.7	55.0	0.0	0.0
P-1	116.0	64.4	54.0	50.8	4.7	0.5
P-3	71.7	60.8	32.0	47.5	8.0	4.0
P-18	61.7	57.5	25.0	44.4	11.1	10.8
P-2	47.4	54.1	10.7	41.2,	14.3	13.9

$$* \frac{\sum(\text{People})(\mu\text{g}/\text{m}^3)}{\sum(\text{People})} = \mu\text{g}/\text{m}^3$$

Table D.1-1. NCIAQCR - Regional Damage Values Summary

Strategy	Total Emission (Tons/Day)	Average Air Quality Weighted With Respect To Population ($\mu\text{g}/\text{m}^3$)*	Point Emission (Tons/Day)	Damage ($\$ \times 10^6$)	Benefit ($\$ \times 10^6$)	Control Cost ($\$ \times 10^6$)
<u>SO₂:</u>						
Existing	156.2	77.4	92.7	34.5	0.0	0.0
S2-10	138.4	71.2	74.9	31.4	3.1	-3.696
S3-14	129.7	63.1	66.2	27.3	7.2	0.971
S4-15	110.8	59.4	47.3	25.4	9.1	3.768
S5-11	63.5	37.2	0.0	14.2	20.3	27.214
<u>Particulates:</u>						
Existing	54.9	77.4	31.9	24.2	0.0	0.0
P2-1	32.9	70.8	9.9	21.8	2.4	0.441
P3-3	32.9	67.2	9.9	20.6	3.6	0.441
P4-18	27.0	61.2	4.2	18.4	5.8	8.415
P5-2	23.9	56.8	0.9	16.8	7.4	6.336

*
$$\frac{\sum (\text{People})(\mu\text{g}/\text{m}^3)}{\sum (\text{People})} = \mu\text{g}/\text{m}^3$$

Table D.1-2. NCIAQCR: Damage Summary for Political Jurisdiction #1 - District of Columbia

Strategy	Average Air Quality		Point Emission (Tons/Day)	Damage (\$ x 10 ⁶)	Benefit (\$ x 10 ⁶)	Control Cost (\$ x 10 ⁶)
	Total Emission (Tons/Day)	Weighted With Respect To Population (µg/m ³)*				
<u>SO₂:</u>						
Existing	174.1	54.2	161.0	10.2	0.0	0.0
S2-10	88.2	46.6	75.0	8.5	1.7	-0.052
S3-14	62.6	44.2	49.5	7.9	2.3	0.873
S4-15	47.7	41.0	34.5	7.3	2.9	2.315
S5-11	13.2	35.9	0.0	6.1	4.1	13.642
<u>Particulates:</u>						
Existing	23.6	62.3	13.7	8.4	0.0	0.0
P2-1	22.0	59.7	12.1	8.0	.4	-0.034
P3-3	10.1	55.4	0.2	7.3	1.1	-7.377
P4-18	10.6	55.3	0.7	7.3	1.1	-7.786
P5-2	10.2	52.7	0.3	6.8	1.6	-7.323

$$* \frac{\sum (\text{People})(\mu\text{g}/\text{m}^3)}{\sum (\text{People})} = \mu\text{g}/\text{m}^3$$

Table D.1-3. NCIAQCR: Damage Summary for Political Jurisdiction #2 - Montgomery County

Strategy	Average Air Quality		Point Emission (Tons/Day)	Damage (\$ x 10 ⁶)	Benefit (\$ x 10 ⁶)	Control Cost (\$ x 10 ⁶)
	Total Emission (Tons/Day)	Weighted With Respect To Population (µg/m ³)*				
<u>SO₂:</u>						
Existing	193.5	69.8	178.5	14.3	0.0	0.0
S2-10	100.1	61.1	85.1	12.2	2.1	0.286
S3-14	71.0	55.6	56.0	10.9	3.4	1.616
S4-15	52.7	51.7	37.7	10.0	4.3	3.249
S5-11	15.0	37.0	0.0	6.6	7.7	26.032
Particulates:						
Existing	30.3	74.9	12.7	10.8	0.0	0.0
P2-1	28.6	66.9	11.0	9.5	1.3	0.066
P3-3	18.5	61.4	0.9	8.6	2.2	2.216
P4-18	20.7	58.4	3.1	8.1	2.7	1.397
P5-2	19.9	56.3	2.3	7.7	3.1	2.216

$$* \frac{\sum (\text{People})(\mu\text{g}/\text{m}^3)}{\sum (\text{People})} = \mu\text{g}/\text{m}^3$$

Table D.1-4. NCIAQCR: Damage Summary for Political Jurisdiction #3 - Prince Georges County

Strategy	Total Emission (Tons/Day)	Average Air Quality Weighted With Respect To Population ($\mu\text{g}/\text{m}^3$)*	Point Emission (Tons/Day)	Damage ($\$ \times 10^6$)	Benefit ($\$ \times 10^6$)	Control Cost ($\$ \times 10^6$)
<u>SO₂:</u>						
Existing	55.7	54.6	50.7	4.9	0.0	0.0
S2-10	55.7	47.2	50.7	4.1	.8	0.0
S3-14	44.4	44.7	39.4	3.9	1.0	0.733
S4-15	33.1	42.4	28.2	3.6	1.3	1.893
S5-11	5.0	35.8	0.0	2.9	2.0	18.393
<u>Particulates:</u>						
Existing	10.9	62.0	7.7	4.0	0.0	0.0
P2-1	10.9	59.4	7.7	3.8	.2	0.0
P3-3	10.9	57.4	7.7	3.6	.4	0.0
P4-18	6.9	55.9	3.7	3.5	.5	0.032
P5-2	3.3	51.6	0.1	3.2	.8	1.205

$$* \frac{\Sigma(\text{People})(\mu\text{g}/\text{m}^3)}{\Sigma(\text{People})} = \mu\text{g}/\text{m}^3$$

Table D.1-5. NCIAQCR: Damage Summary for Political Jurisdiction #4 - Alexandria City

Average Air Quality						
Strategy	Total Emission (Tons/Day)	Weighted With Respect To Population ($\mu\text{g}/\text{m}^3$)*	Point Emission (Tons/Day)	Damage ($\$ \times 10^6$)	Benefit ($\$ \times 10^6$)	Control Cost ($\$ \times 10^6$)
<u>SO₂:</u>						
Existing	12.3	47.8	5.3	6.7	0.0	0.0
S2-10	12.3	39.6	5.3	5.3	1.4	0.0
S3-14	10.8	38.5	3.7	5.1	1.6	0.840
S4-15]	9.8	35.2	2.7	4.5	2.2	1.125
S5-11	7.1	34.5	0.0	4.4	2.3	1.844
<u>Particulates:</u>						
Existing	4.8	55.1	1.5	5.6	0.0	0.0
P2-1	4.8	52.9	1.5	5.3	.3	0.0
P3-3	4.8	51.5	1.5	5.1	.5	0.0
P4-18	4.8	50.9	1.5	5.0	.6	0.0
P5-2	3.4	48.5	0.1	4.7	.9	0.784

$$* \frac{\Sigma(\text{People})(\mu\text{g}/\text{m}^3)}{\Sigma(\text{People})} = \mu\text{g}/\text{m}^3$$

Table D.1-6. NCIAQCR: Damage Summary for Political Jurisdiction #5 - Arlington County

Strategy	Average Air Quality Weighted With Respect To Population ($\mu\text{g}/\text{m}^3$)*					Point Emission (Tons/Day)	Damage (\$ x 10 ⁶)	Benefit (\$ x 10 ⁶)	Control Cost (\$ x 10 ⁶)
	Total Emission (Tons/Day)								
<u>SO₂:</u>									
Existing	14.1	53.8	2.8	2.7	0.0				
S2-10	14.1	46.3	2.8	2.2	.5				
S3-14	13.4	43.9	2.1	2.1	.6	0.341			
S4-15	12.8	40.9	1.5	1.9	.8	0.514			
S5-11	11.3	35.4	0.0	1.6	1.1	0.935			
<u>Particulates:</u>									
Existing	22.7	63.8	8.7	2.3	0.0				
P2-1	21.4	61.3	7.4	2.2	.1	0.033			
P3-3	21.4	59.3	7.4	2.1	.2	0.033			
P4-18	21.4	54.6	7.4	1.9	.4	0.033			
P5-2	20.9	50.6	6.9	1.7	.6	0.955			

$$* \frac{\sum (\text{People})(\mu\text{g}/\text{m}^3)}{\sum (\text{People})} = \mu\text{g}/\text{m}^3$$

Table D.1-7. NCIAQCR: Damage Summary for Political Jurisdiction #6 - Fairfax County

Strategy	Total Emission (Tons/Day)	Average Air Quality Weighted With Respect To Population ($\mu\text{g}/\text{m}^3$)*	Point Emission (Tons/Day)	Damage ($\$ \times 10^6$)	Benefit ($\$ \times 10^6$)	Control Cost ($\$ \times 10^6$)
<u>SO₂:</u>						
Existing	0.5	47.3	0.0	0.26	0.0	0.0
S2-10	0.5	40.4	0.0	0.21	.05	0.0
S3-14	0.5	39.1	0.0	0.20	.06	0.0
S4-15	0.5	36.0	0.0	0.18	.08	0.0
S5-11	0.5	34.8	0.0	0.17	.09	0.0
<u>Particulates:</u>						
Existing	0.5	55.9	0.0	0.22	0.0	0.0
P2-1	0.5	53.7	0.0	0.21	.01	0.0
P3-3	0.5	52.2	0.0	0.20	.02	0.0
P4-18	0.5	51.8	0.0	0.20	.02	0.0
P5-2	0.5	49.1	0.0	0.19	.03	0.0

$$* \frac{\sum (\text{People}) (\mu\text{g}/\text{m}^3)}{\sum (\text{People})} = \mu\text{g}/\text{m}^3$$

Table D.1-8. NCIAQCR: Damage Summary for Political Jurisdiction #7 - Falls Church City

SO ₂ Strategy/ Particulate Strategy	Average SO ₂ Air Quality Weighted With Respect To Population (µg/m ³)*	Average Particulate Air Quality Weighted With Respect To Population (µg/m ³)*	Total Type I Property Value \$x10 ⁶	Total Benefit \$x10 ⁶	Average Type I Property Value \$	Average Benefit Per Household \$	SO ₂ Control Cost \$x10 ⁶	Partic- ulate Control Cost \$x10 ⁶	Total Control Cost \$x10 ⁶
Existing/Existing	66.7	70.9	5,329.	0.0	22,365	0.0	0.0	0.0	0.0
10/1	59.8	65.6	5,401.	72.	22,664.	499.	-3.5	0.5	-3.0
14/3	54.4	61.8	5,448.	47.	22,863.	199.	6.1	4.0	10.1
15/18	40.8	58.1	5,489.	41.	23,034.	171.	14.6	10.8	25.4
11/2	36.5	54.6	5,602.	113.	23,507.	473.	104.5	13.9	118.4

$$* \frac{\sum(\text{People})(\mu\text{g}/\text{m}^3)}{\sum(\text{People})} = \mu\text{g}/\text{m}^3$$

Table D.2-1. Type I Property Values: NCIAQCR Regional Summary

SO ₂ Strategy/ Particulate Strategy	Average SO ₂ Air Quality Weighted With Respect To Population (µg/m ³)*	Average Particulate Air Quality Weighted With Respect To Population (µg/m ³)*	Total Type I Property Value \$x10 ⁶	Total Benefit \$x10 ⁶	Average Type I Property Value \$	Average Benefit Per Household \$	SO ₂ Control Cost \$x10 ⁶	Partic- ulate Control Cost \$x10 ⁶	Total Control Cost \$x10 ⁶
Existing/Existing	79.0	78.5	1,298.	0.	20,117.	0.0	0.0	0.0	0.0
10/1	73.0	71.4	1,313.	15.	20,349.	232.	-3.696	-0.441	-3.255
14/3	64.5	67.8	1,328.	15.	20,588.	239.	0.971	0.441	1.412
15/18	60.7	61.5	1,342.	14.	20,793.	205.	3.768	8.415	12.183
11/2	37.2	57.1	1,393.	51.	21,586.	793.	27.214	6.336	33.550

$$* \frac{\sum(\text{People})(\mu\text{g}/\text{m}^3)}{\sum(\text{People})} = \mu\text{g}/\text{m}^3$$

Table D.2-2. Type I Property Values: Political Jurisdiction 1, District of Columbia Summary

SO ₂ Strategy/ Particulate Strategy	Average SO ₂ Air Quality Weighted With Respect To Population (µg/m ³)*	Average Particulate Air Quality Weighted With Respect To Population (µg/m ³)*	Total Type I Property Value \$x10 ⁶	Total Benefit \$x10 ⁶	Average Type I Property Value \$	Average Benefit Per Household \$	SO ₂ Control Cost \$x10 ⁶	Partic- ulate Control Cost \$x10 ⁶	Total Control Cost \$x10 ⁶
Existing/Existing	54.6	63.1	1,427.	0.	25,098	0.0	0.0	0.0	0.0
10/1	47.6	60.5	1,444.	17.	25,400.	302.	-.052	-.034	-.086
14/3	45.0	55.9	1,456.	12.	25,615.	215.	.873	-7.377	-6.504
15/12	41.8	55.8	1,463.	7.	25,746.	131.	2.315	-7.788	-5.471
11/2	36.0	53.1	1,482.	19.	26,073.	328.	13.642.	-7.323	6.319

188

$$\frac{\sum(\text{People})(\mu\text{g}/\text{m}^3)}{\sum(\text{People})} = \mu\text{g}/\text{m}^3$$

Table D.2-3. Type I Property Values: Political Jurisdiction 2, Montgomery County, Md. Summary

SO ₂ Strategy/ Particulate Strategy	Average SO ₂ Air Quality Weighted With Respect To Population (µg/m ³)*	Average Particulate Air Quality Weighted With Respect To Population (µg/m ³)*	Total Type I Property Value \$x10 ⁶	Total Benefit \$x10 ⁶	Average Type I Property Value \$	Average Benefit Per Household \$	SO ₂ Control Cost \$x10 ⁶	Partic- ulate Control Cost \$ 10 ⁶	Total Control Cost \$x10 ⁶
Existing/Existing	73.1	78.4	978.	0.	20,382.	0.0	0.0	0.0	0.0
10/1	64.8	69.2	994.	16.	20,713.	331.	.286	.066	.352
14/3	58.5	63.3	1,006.	12.	20,973.	260.	1.616	2.216	3.832
15/8	54.4	59.6	1,015.	9.	21,154.	181.	3.249	1.397	4.646
11/2	37.3	57.3	1,044.	29.	21,763.	609.	26.032	2.216	28.248

$$\frac{\sum(\text{People})(\mu\text{g}/\text{m}^3)}{\sum(\text{People})} = \mu\text{g}/\text{m}^3$$

Table D.2-4. Type I Property Values: Political Jurisdiction 3, Prince Georges Co., Md., Summary

SO ₂ Strategy/ Particulate Strategy	Average SO ₂ Air Quality Weighted With Respect To Population (µg/m ³)*	Average Particulate Air Quality Weighted With Respect To Population (µg/m ³)*	Total Type I Property Value \$x10 ⁶	Total Benefit \$x10 ⁶	Average Type I Property Value \$	Average Benefit Per Household \$	SO ₂ Control Cost \$x10 ⁶	Partic- ulate Control Cost \$x10 ⁶	Total Control Cost \$x10 ⁶
Existing/Existing	54.1	61.9	453.	0.	22,992.	0.0	0.0	0.0	0.0
10/1	47.0	59.3	458.	5.	23,259.	267.	0.0	0.0	0.0
14/3	44.5	57.4	460.	2.	23,389.	130.	.733	0.0	.733
15/18	42.3	55.9	463.	3.	23,519.	130.	1.873	0.032	1.928
11/2	35.8	51.6	470.	7.	23,861.	342.	18.333	1.205	19.588

$$\frac{\sum(\text{People})(\mu\text{g}/\text{m}^3)}{\sum(\text{People})} = \mu\text{g}/\text{m}^3$$

Table D.2-5. Type I Property Values: Political Jurisdiction 4, Alexandria, Va. Summary

SO ₂ Strategy/ Particulate Strategy	Average SO ₂ Air Quality Weighted With Respect To Population (µg/m ³)*	Average Particulate Air Quality Weighted With Respect To Population (µg/m ³)*	Total Type I Property Value \$x10 ⁶	Total Benefit \$x10 ⁶	Average Type I Property Value \$	Average Benefit Per Household \$	SO ₂ Control Cost \$x10 ⁶	Partic- ulate Control Cost \$x10 ⁶	Total Control Cost \$x10 ⁶
Existing/Existing	48.3	55.6	1,001.	0.	24,297.	0.0	0.0	0.0	0.0
10/1	40.2	53.5	1,017.	16.	24,646.	349.	0.0	0.0	0.0
14/3	39.0	52.0	1,021.	4.	24,772.	126.	.840	0.0	.840
15/18	35.7	51.3	1,028.	7.	24,947.	175.	1.125	0.0	1.125
11/2	34.7	48.7	1,033.	5.	25,071.	124.	1.844	.784	2.628

$$\frac{\sum(\text{People})(\mu\text{g}/\text{m}^3)}{\sum(\text{People})} = \mu\text{g}/\text{m}^3$$

Table D.2-6. Type I Property Values: Political Jurisdiction 5, Arlington Co., Va., Summary

SO ₂ Strategy/ Particulate Strategy	Average SO ₂ Air Quality Weighted With Respect To Population (µg/m ³)*	Average Particulate Air Quality Weighted With Respect To Population (µg/m ³)*	Total Type I Property Value \$x10 ⁶	Total Benefit \$x10 ⁶	Average Type I Property Value \$	Average Benefit Per Household \$	SO ₂ Control Cost \$x10 ⁶	Partic- ulate Control Cost \$x10 ⁶	Total Control Cost \$x10 ⁶
Existing/Existing	53.7	64.3	130.	0.	20,531.	0.0	0.0	0.0	0.0
10/1	46.4	61.7	132.	2.	20,802.	271.	0.0	.033	.033
14/3	44.0	59.8	132.	0.	20,914.	112.	.341	.033	.374
15/18	41.0	54.6	134.	2.	21,119.	205.	.514	.033	.547
11/2	35.5	50.7	135.	1.	21,387.	268.	.935	.955	1.890

$$\frac{\sum(\text{People})(\mu\text{g}/\text{m}^3)}{\sum(\text{People})} = \mu\text{g}/\text{m}^3$$

Table D.2-7. Type I Property Values: Political Jurisdiction 6, Fairfax Co., Va. Summary

SO ₂ Strategy/ Particulate Strategy	Average SO ₂ Air Quality Weighted With Respect To Population (µg/m ³)*	Average Particulate Air Quality Weighted With Respect To Population (µg/m ³)*	Total Type I Property Value \$x10 ⁶	Total Benefit \$x10 ⁶	Average Type I Property Value \$	Average Benefit Per Household \$	SO ₂ Control Cost \$x10 ⁶	Partic- ulate Control Cost \$x10 ⁶	Total Control Cost \$x10 ⁶
	Existing/Existing								
	47.3	55.9	44.	0.	24,887.	0.0	0.0	0.0	0.0
10/1	40.4	53.7	44.	0.	25,299.	412.	0.0	0.0	0.0
14/3	39.1	52.2	44.	0.	25,333.	34.	0.0	0.0	0.0
15/18	36.0	51.8	45.	1.	25,491.	158.	0.0	0.0	0.0
11/2	34.8	49.1	45.	0.	25,646.	155.	0.0	0.0	0.0

$$\frac{\sum(\text{People})(\mu\text{g}/\text{m}^3)}{\sum(\text{People})} = \mu\text{g}/\text{m}^3$$

Table D.2-8. Type I Property Values: Political Jurisdiction 7, Falls Church, Va. Summary

SO ₂ Strategy/ Particulate Strategy	Average SO ₂ Air Quality Weighted With Respect To Population (µg/m ³) *	Average Particulate Air Quality Weighted With Respect To Population (µg/m ³) *	Total MPV (\$x10 ⁶)	Average MPV (\$)	Total Type I Bid Before Shift (\$x10 ⁶)	Average Type I Bid Before Shift (\$)	Total Type I Bid After Shift (\$x10 ⁶)	Average Type I Bid After Shift (\$)	Total Difference (\$x10 ⁶)	Average Difference (\$)
Existing/Existing	66.7	70.9	4,172.	17506.	5,329	22365.	4,879.	20,475.	-450.	-1890.
10/1	59.8	65.4	4,172.	17506.	5,401.	22664.	4,941.	20,735.	-460.	-1929.
14/3	54.4	61.8	4,172.	17506.	5,448.	22863.	4,982.	20,907.	-466.	-1956.
15/18	50.8	58.1	4,172.	17506.	5,489.	23034.	5,019.	21,066.	-469.	-1968.
11/2	36.5	54.6	4,172.	17506.	5,602.	23507.	5,100.	21,402.	-501.	-2105.

$$\frac{* \Sigma(\text{People})(\mu\text{g}/\text{m}^3)}{\Sigma(\text{People})} = \mu\text{g}/\text{m}^3$$

Table D.3-1. Adjusted Type I Property Values: NCIAQCR, Regional Summary

SO ₂ Strategy/ Particulate Strategy	Average SO ₂ Air Quality Weighted With Respect To Population (µg/m ³) *	Average Particulate Air Quality Weighted With Respect To Population (µg/m ³) *	Total MPV (\$x10 ⁶)	Average MPV (\$)	Total Type I Bid Before Shift (\$x10 ⁶)	Average Type I Bid Before Shift (\$)	Total Type I Bid After Shift (\$x10 ⁶)	Average Type I Bid After Shift (\$)	Total Difference (\$x10 ⁶)	Average Difference (\$)
Existing/Existing	79.0	78.5	982.	15227.	1,298.	20117.	1,708.	26467.	410.	6350.
10/1	73.0	71.4	982.	15227.	1,313.	20349.	1,724.	26726.	411.	6377.
14/3	64.5	67.8	982.	15227.	1,328.	20588.	1,750.	27126.	422.	6538.
15/18	60.7	61.5	982.	15227.	1,342.	20793.	1,772.	27471.	431.	6679.
11/2	37.2	57.1	982.	15227.	1,393.	21586.	1,869.	28972.	477.	7386.

$$\frac{\sum(\text{People})(\mu\text{g}/\text{m}^3)}{\sum(\text{People})} = \mu\text{g}/\text{m}^3$$

Table D.3-2. Adjusted Type I Property Values - Political Jurisdiction 1, District of Columbia

SO ₂ Strategy/ Particulate Strategy	Average SO ₂ Air Quality Weighted With Respect To Population (µg/m ³) *	Average Particulate Air Quality Weighted With Respect To Population (µg/m ³) *	Total MPV (\$x10 ⁶)	Average MPV (\$)	Total Type I Bid Before Shift (\$x10 ⁶)	Average Type I Bid Before Shift (\$)	Total Type I Bid After Shift (\$x10 ⁶)	Average Type I Bid After Shift (\$)	Total Difference (\$x10 ⁶)	Average Difference (\$)
Existing/Existing	54.6	63.1	1,181.	20775.	1,427.	25098	957.	16840	-469.	-8258.
10/1	47.6	60.5	1,181.	20775.	1,444.	25400.	959.	16880.	-484.	-8520.
14/3	45.0	55.9	1,181.	20775.	1,456.	25615.	966.	16990.	-490.	-8625.
15/18	41.8	55.8	1,181.	20775.	1,463.	25746.	963.	16943.	-500.	-8803.
11/2	36.0	53.1	1,181.	20775.	1,482.	26074.	934.	16438.	-578.	-9636.

$$\frac{\sum(\text{People})(\mu\text{g}/\text{m}^3)}{\sum(\text{People})} = \mu\text{g}/\text{m}^3$$

Table D.3-3. Adjusted Type I Property Values - Political Jurisdiction 2, Montgomery County

SO ₂ Strategy/ Particulate Strategy	Average SO ₂ Air Quality Weighted With Respect To Population ($\mu\text{g}/\text{m}^3$) *	Average Particulate Air Quality Weighted With Respect To Population ($\mu\text{g}/\text{m}^3$) *	Total MPV ($\$ \times 10^6$)	Average MPV ($\$$)	Total Type I Bid Before Shift ($\$ \times 10^6$)	Average Type I Bid Before Shift ($\$$)	Total Type I Bid After Shift ($\$ \times 10^6$)	Average Type I Bid After Shift ($\$$)	Total Difference ($\$ \times 10^6$)	Average Difference ($\$$)
Existing/Existing	73.1	78.4	716.	14936.	978.	20382.	794.	16550.	-184.	-3831.
10/1	64.8	64.2	716.	14936.	994.	20713.	813.	16955.	-180.	-3759.
14/3	58.5	63.3	716.	14936.	1,006.	20973.	837.	17449.	-169.	-3524.
15/18	54.4	59.6	716.	14936.	1,015.	21154.	849.	17703.	-166.	-3451.
11/2	37.3	57.3	716.	14936.	1,044.	21763.	912.	19019.	-132.	-2744.

$$\frac{\sum(\text{People})(\mu\text{g}/\text{m}^3)}{\sum(\text{People})} = \mu\text{g}/\text{m}^3$$

Table D.3-4. Adjusted Type I Property Values - Political Jurisdiction 3, Prince Georges County

SO ₂ Strategy/ Particulate Strategy	Average SO ₂ Air Quality Weighted With Respect To Population (µg/m ³)*		Average Particulate Air Quality Weighted With Respect To Population (µg/m ³)*		Total MPV (\$x10 ⁶)		Average MPV (\$)		Total Type I Bid Before Shift (\$x10 ⁶)		Average Type I Bid Before Shift (\$)		Total Type I Bid After Shift (\$x10 ⁶)		Average Type I Bid After Shift (\$)		Total Difference (\$x10 ⁶)		Average Difference (\$)	
Existing/Existing	54.1		61.9		357.	18111.	453.	22992.	345.	17510.	-5482.	-108.	-5482.							
10/1	47.0		59.3		357.	18111.	458.	23259.	345.	17554.	-5705.	-112.	-5705.							
14/3	44.5		57.4		357.	18111.	460.	23389.	342.	17367.	-6022	-119.	-6022							
15/18	42.3		55.9		357.	18111.	463.	23519.	340.	17286.	-6229.	-122.	-6229.							
11/2	55.8		51.9		357.	18111.	470.	23861.	339.	17196.	-6665.	-131.	-6665.							

$$\frac{\sum(\text{People})(\mu\text{g}/\text{m}^3)}{\sum(\text{People})} = \mu\text{g}/\text{m}^3$$

Table D.3-5. Adjusted Type I Property Values - Political Jurisdiction 4, Alexandria

SO ₂ Strategy/ Particulate Strategy	Average SO ₂ Air Quality Weighted With Respect To Population (µg/m ³) *	Average Particulate Air Quality Weighted With Respect To Population (µg/m ³) *	Total MPV (\$x10 ⁶)	Average MPV (\$)	Total Type I Bid Before Shift (\$x10 ⁶)	Average Type I Bid Before Shift (\$)	Total Type I Bid After Shift (\$x10 ⁶)	Average Type I Bid After Shift (\$)	Total Difference (\$x10 ⁶)	Average Difference (\$)
Existing/Existing	48.3	55.6	798.	19366.	1,001.	24297.	900.	21836.	-101.	-2461.
10/1	40.2	53.5	798.	19366.	1,017.	24676.	922.	22357.	-96.	-2319.
14/3	39.0	52.0	798.	19366.	1,021.	24772.	911.	22114.	-110.	-2658.
15/18	35.7	51.3	798.	19366.	1,028.	24947.	917.	22241.	-112.	-2706.
11/2	34.7	48.7	798.	19366.	1,033.	25071.	872.	21154.	-161.	-3916.

$$\frac{* \Sigma(\text{People})(\mu\text{g}/\text{m}^3)}{\Sigma(\text{People})} = \mu\text{g}/\text{m}^3$$

Table D.3-6. Adjusted Type I Property Values - Political Jurisdiction 5, Arlington County

SO ₂ Strategy/ Particulate Strategy	Average SO ₂ Air Quality Weighted With Respect To Population ($\mu\text{g}/\text{m}^3$) *	Average Particulate Air Quality Weighted With Respect To Population ($\mu\text{g}/\text{m}^3$) *	Total MPV (\$x10^6)	Average MPV (\$)	Total Type I Bid Before Shift (\$x10^6)	Average Type I Bid Before Shift (\$)	Total Type I Bid After Shift (\$x10^6)	Average Type I Bid After Shift (\$)	Total Difference (\$x10^6)	Average Difference (\$)
Existing/Existing	53.7	64.3	102.	16100.	130.	20531.	139.	21968.	9.	1437.
10/1	46.4	61.7	102.	16100.	132.	20802.	140.	22062.	8.	1260.
14/3	44.0	59.8	102.	16100.	132.	20914.	139.	21975.	7.	1062.
15/18	41.0	54.6	102.	16100.	134.	21119.	141.	22322.	8.	1203.
11/2	35.5	50.7	102.	16100.	135.	21387.	138.	21745.	2.	359.

$$\frac{*I(\text{People})(\mu\text{g}/\text{m}^3)}{I(\text{People})} = \mu\text{g}/\text{m}^3$$

Table D.3-7. Adjusted Type I Property Values - Political Jurisdiction 6, Fairfax County

SO ₂ Strategy/ Particulate Strategy	Average SO ₂ Air Quality Weighted With Respect To Population ($\mu\text{g}/\text{m}^3$) *	Average Particulate Air Quality Weighted With Respect To Population ($\mu\text{g}/\text{m}^3$) *	Total MPV ($\$ \times 10^6$)	Average MPV ($\$$)	Total Type I Bid Before Shift ($\$ \times 10^6$)	Average Type I Bid Before Shift ($\$$)	Total Type I Bid After Shift ($\$ \times 10^6$)	Average Type I Bid After Shift ($\$$)	Total Difference ($\$ \times 10^6$)	Average Difference ($\$$)
Existing/Existing	47.3	55.9	35.	20208.	44.	24887.	37.	21035.	-7.	-3852.
10/1	40.4	53.7	35.	20208.	44.	25229.	37.	21397.	-7.	-3832.
14/3	39.1	52.2	35.	20208.	44.	25333.	37.	21207.	-7.	-4126.
15/18	36.0	51.8	35.	20208.	45.	25491.	37.	21269.	-7.	-4222.
11/2	34.8	49.1	35.	20208.	45.	25646.	36.	20797.	-8.	-4848.

$$\frac{\sum(\text{people})(\mu\text{g}/\text{m}^3)}{\sum(\text{people})} = \mu\text{g}/\text{m}^3$$

Table D.3-8. Adjusted Type I Property Values - Political Jurisdiction 7, Falls Church

BLANK PAGE

APPENDIX E
USER'S MANUAL FOR THE BENEFITS SEGMENT
OF THE RAPA COST/BENEFIT MODEL

1.0 INTRODUCTION

The existing version of the RAPA Cost/Benefit Model Segment is a prototype of the cost/benefit computer model originally conceived for the RAPA program. As a prototype, it has been designed in complete modular form, allowing easy modification and expansion. It is expected that desirable changes will become apparent as the model is applied in the context of actual studies. In fact, the results of the NCIAQCR demonstration presented in this report have already pointed the way toward future program development.

Figure E.1-1 illustrates the overall system flow for the RAPA Cost/Benefit Model. It also provides a convenient cross-reference for the figures and subsections of this appendix which pertain to the individual modules and their input/output. As currently designed, the Benefits Segment consists of an interface module (CONVRT), and a series of analysis modules (DAMAGE, PROP, ASSIGN). The Interface Module provides the only automatic data processing interface with the Implementation Planning Program, which serves as the Cost Segment. Each of the analysis modules are completely independent of one another; they individually receive input from the Interface Module and a common census tract attribute data deck.

The remaining sections of this chapter present input formats, complete sample outputs, program listings, Job Control Language (JCL) cards and other information of assistance to the program user. All of the modules are written in FORTRAN IV (Level G) and are designed to run on an IBM System 360 computer with a monitoring system (the machine employed for the demonstration was a model 50). The presentation in this appendix assumes that

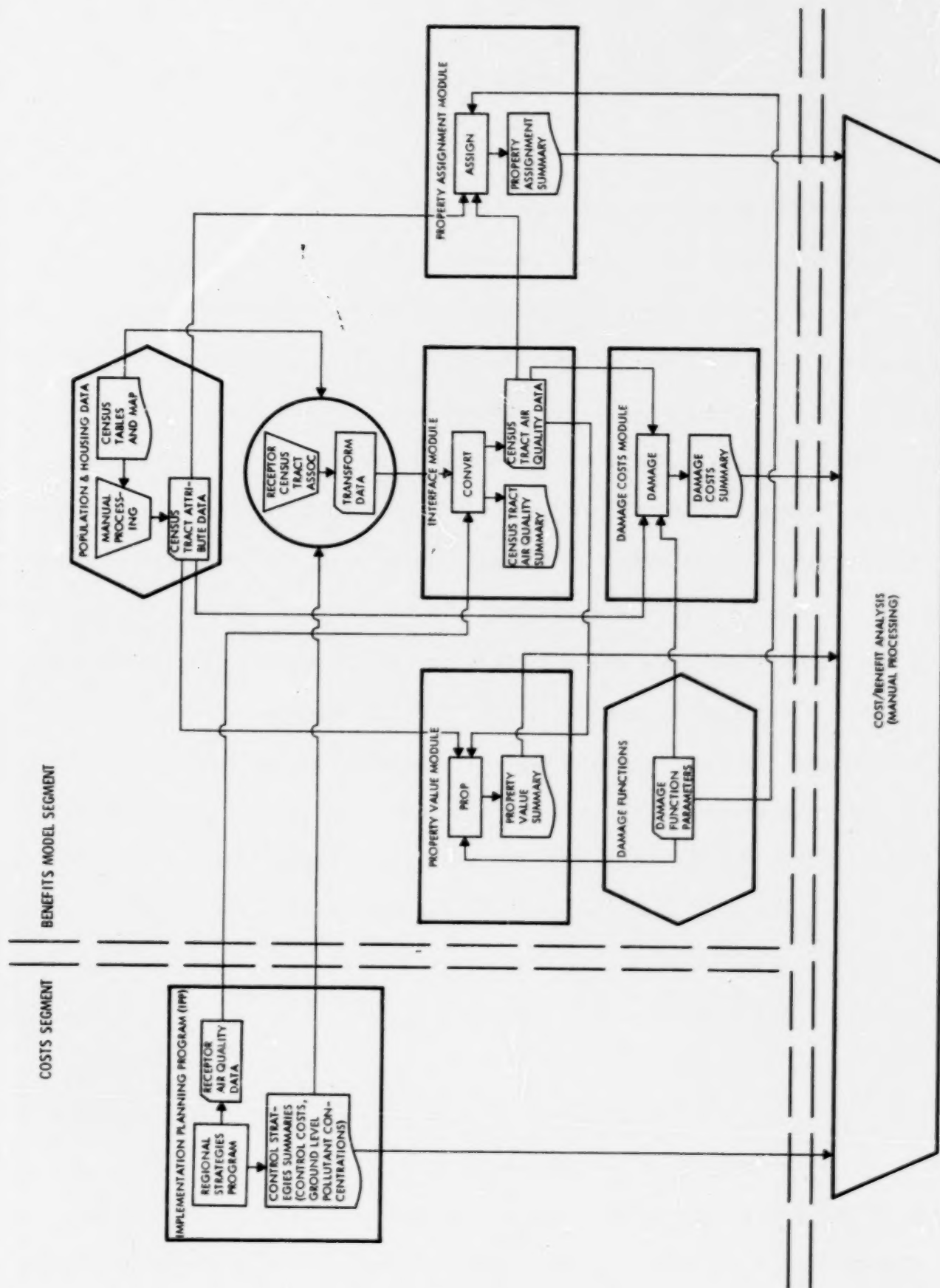


Figure E.1-1. Overall System Flow

all required input is in the form of punched cards. However, if a disk pack is available at the user's facility, the JCL cards can be readily modified so that all module interfaces occur via disk (or magnetic tape). This approach was actually followed for the demonstration runs.

2.0 CENSUS TRACT ATTRIBUTE DATA

The data deck of census tract attributes provides a common input for all of the analysis modules of the Benefits Segment. Two data cards are required for each census tract in the region, plus a title card (one per region). Consequently, for the NCIAQCR demonstration, a total of $(2 \times 366) + 1 = 733$ census tract attribute cards were required.

The complete format information for the title card and the two data cards is given in Table E.2-1. In the table, KCT is the individual census tract identification number. The quotients Q1 and Q2 are used to test for the different categories of census tract property values (see Section 3.5); Q1 is used to distinguish Type I and Type II census tracts, and Q2 is used to test for Type III and Type IV census tracts, i.e.,

$$Q1 = \frac{P\emptyset P}{MIL}, \quad Q2 = \frac{SFH}{ALL}.$$

The above parameters (P $\emptyset$ P, MIL, SFH, ALL), as well as the others listed in Table E.2-1, have been identified in Section 2.3 and are listed in Table E.3-1. In general, the information given on the first census tract attribute card is required for identification purposes and output information. The second card contains the attributes (already in natural log form) used in the regression equations.

Table E.2-1.

Format Information for Census Tract Attribute Data Cards

<u>Parameter</u>	<u>Columns</u>	<u>Format</u>
<u>CARD 1</u> (ONE CARD ONLY PER REGION)		
TITLE1	1-80	20A4
-left justified, beginning in column three		
<u>CARD 2</u>		
KCT	1-9	2A4,A1
(Blank)	10	1X
Q1	11-16	F6.2
Q2	17-22	F6.3
PØP	23-30	F8.2
MIL	31-38	F8.2
SFH	39-46	F8.2
ALL	47-54	F8.2
ØWN	55-62	F8.2
RENT	63-70	F8.2
<u>CARD 3</u>		
KCT	1-9	2A4,A1
(Blank)	10	1X
MPV	11-18	F8.2
MGR	19-25	F7.2
MCR	26-32	F7.2
Ln(MFI)	33-40	F8.3
Ln(DLP)	41-48	F8.3
Ln(ØLD)	49-56	F8.3
Ln(NWT)	57-64	F8.3
Ln(DIS)	65-72	F8.3
Ln(MRM)	73-80	F8.4

Repeat cards 2 and 3 for each census tract in the region.

The individual analysis modules only read into core a subset of the attributes given on these cards. The remaining sections of this appendix, on the individual modules, indicate the specific attributes used.

3.0 INTERFACE MODULE

3.1 DESCRIPTION

The Interface Module (CØNVRT) accepts receptor point pollutant concentration data (particulate matter or sulfur dioxide) in punched card form, as produced by the Regional Strategies Segment of IPP*, and calculates the corresponding mean concentrations for each census tract (CTPC) in the region. The CTPC data are output for use in the analysis module of the Benefits Segment (Figure E.1-1).

3.2 JOB CONTROL LANGUAGE AND DECK SET-UP

Figure E.3-1 illustrates the JCL and sample deck set-up for CØNVRT. The deck set-up indicates the presence of source programs and object programs. In practice, the user may want to run all source decks (e.g., if a code modification has been made requiring recompilation), all object programs or a combination of both. The last option is a possibility since the CØNVRT module has three main parts: the DRIVER or main program, CØNVRT subprogram and subroutine ØRDER. If the user confines code modifications to any one of these parts, he need only recompile the source deck for that part; the remaining program parts can be in the form of object (compiled machine language) decks. It is recommended that the user retain the JCL as shown and include or exclude the source or object decks as desired.

*A similar punched card deck is output from the IPP Air Pollutant Concentration Segment, but it is in a format which is incompatible with the Benefits Segment.

JOB SETUP FOR CONVRT MODEL

```
//CONVRT EXEC PROC=FONTGCLG  
//FONT.SYSIN DD *
```

SOURCE DECKS

```
/*  
//LKED.SYSIN DD *
```

OBJECT DECKS

```
/*  
//GO.FT05F001 DD *
```

TRANSFORM DATA DECK

```
/*  
//GO.FT05F002 DD *
```

AIR QUALITY DATA DECK #1 (FROM IPP)

```
/*  
//GO.FT05F003 DD *
```

AIR QUALITY DATA DECK #2 (FROM IPP)

```
/*  
//GO.FT05F004 DD *
```

AIR QUALITY DATA DECK #3 (FROM IPP)

```
/*  
//GO.FT05F005 DD *
```

AIR QUALITY DATA DECK #4 (FROM IPP)

```
/*  
//GO.FT05F006 DD DUMMY  
/*
```

Figure E.3-1. Job Control Language and Deck Set-Up
for Interface Module (CONVRT)

The object and/or source decks are followed by the transform data deck and the IPP air quality deck(s) (receptor point pollutant concentration data). The example shows four air quality decks. CONVERT utilizes the FORTRAN END option which permits the user to process, in sequence, from one to 999 individual air quality/strategy decks produced by the Regional Strategies Segment of IPP. He need only include the JCL cards illustrated being sure to increase the sequence number by one for each deck and ending with the //GØ.FT05FXXX DD DUMMY card and End Of File (/*) as shown. The sequence number is the last three digits in the above expression, signified by XXX. Thus, in order to process "N" air quality decks, the last portion of the program deck should be:

```
//GØ.FT05FXXX DD *  
      AIR QUALITY DATA DECK "N"  
/*  
//GØ.FT05FYYY DD DUMMY  
/*
```

, where XXX=N+1 and YYY=N+2.

For more specific information on JCL, the user is referred to the appropriate IBM manuals. In addition, the systems programmers at the user's computing facility should be consulted about special features, etc. The format for the transform data deck is shown in Table E.3-1.

Table E.3-1.
Formats for Transform Data Cards

<u>Parameter</u>	<u>Columns</u>	<u>Format</u>
(BLANK)	1	1X
JPJ	2-3	I2
(BLANK)	4	1X
JCT	5-7	I3
JSCT	8	I1
(BLANK)	9	1X
NN(≤ 6)	10	I1
M(1)	11-15	I5
M(2)	16-20	I5
M(3)	21-25	I5
⋮	⋮	⋮
M(NN)	36-40	I5

See Figure E.3-3.

LIN FT05F001 DD *
(NCT cards required)

3.3 DIMENSIONS AND INPUT DATA FORMATS

The listing for the DRIVER or main program of the Interface Module is shown in Figure E.3-2. This portion of the program contains the only dimension information (Figure E.3-2 has values for the NCIAQCR demonstration which must be altered to meet specifics of the AQCR or SMSA of interest. The cards that require dimension changes are indicated by an asterisk in column 80. The principal dimensions are given by:

NCT/XXX/-The number of census tracts, plus one,

NRP/YYY/-The number of receptor points.

For the NCIAQCR region demonstration, there were 366 census tracts. Therefore, XXX was set equal to 367 in the dimension statement. YYY was set equal to 300. The variables: N,JPJ,JCT,JSCT,CTPC and IDCT (Figure E.3-2) are then dimensioned the same as NCT. RPPC is dimensioned the same as NRP. The second dimension in the array M is set equal to the value of NCT; the first dimension is the maximum number of receptor points (6) that may be associated with a given census tract for the purposes of transforming to census tract pollutant concentrations (see Section 3.3.2).

The input/output devices are identified by the data sets:

LIN(X)-input, i.e., card reader.

LOUT(Y)-output, i.e., printer,

LOUT(2)-output, i.e., card punch

In the listing, X=5, Y=6 and Z=7.

The transformation of receptor point pollutant concentration data into census tract pollutant concentration values has been discussed in Chapter 3 (Section 3.3). The program has been designed to accept up to and including six different receptors in association with each census

FORTRAN IV G LEVEL 19	MAIN	DATE = 71133	13/56/24
	C DRIVER FOR CONVERSION ROUTINE		
	C		
0001	DIMENSION N16,367),N1367),JPJ(367),JCT(367),JSCT(367),RPPC(300), 1 CTPC(367),IDCT(367)		•
0002	DATA LIN/5/,LOUT/6/,LIO/7/,NCT/367/,NRP/300/		•
	C		
	C NCT = 366 + 1		•
	C		
0003	CALL CONVRT (LIN,LOUT,LIO,NCT,NRP,M,N,JPJ,JCT,JSCT,RPPC,CTPC,IDCT)		
	C		
0004	STOP		
	C		
0005	END		

Figure E.3-2 DRIVER for Interface Module - Program Listing

tract, when calculating these CTPC values. Table E.3-2 lists the complete data formats for the transform data cards. Figure E.3-2 illustrates the prepared data form used to list receptor numbers of the receptor points selected for the transform.

In Table E.3-2, JPJ is the political jurisdiction number, JCT is the census tract number, and JSCT is the sub-census tract number. NN is the total number of receptor points associated with that census tract for transformation purposes; NN is less than or equal to six. The NN values of M(J) identify these receptor points by the numbering scheme given in Chapter 3 (Section 3.3.2). There should be a total of NCT data cards in the transform data deck.

The receptor point pollutant concentration values are produced by IPP as punched card output. Table E.3-2 provides the complete format data for the air quality data decks indicated in Figure E.1-1. Cards 1 and 2 are not produced by IPP and must be added by the user to the front of the deck (i.e., to the NRP Type 3 data cards from IPP).

The format notation in this table and all other accompanying tables of this appendix follow standard IBM manual notation*. For example, I5 indicates a five place integer, F5.2 indicates a five place fixed point decimal number (including decimal point and sign, if any) with two places after the decimal point, etc. The notation P2F8.0 indicates a FORTRAN scale factor applied to an F8.0 number. In this case, the input value is divided by 100 automatically. In an output format, the value would be multiplied by 100 before printing. The notation (P)F8.0 indicates an implied scale factor (see IBM reference). The variables X and Y are the

* IBM Systems Reference Library, Job Control Language, Form C28-6539-9, Tenth Edition, July 1969.

Table E.3-2.

Receptor Air Quality Data Card Formats

	<u>Parameter</u>	<u>Columns</u>	<u>Format</u>
1 pair per region	<u>CARD 1</u>		
	TITLE	1-80	20A4
	-centered title information		
	<u>CARD 2</u>		
	BACKGR	1-5	F5.2
NRP data cards	<u>CARD 3</u>		
	X	1-8	P2F8.0
	Y	9-16	(P2)F8.0
	PC	17-26	(P2)F10.0

UTM position coordinates of the receptor and PC is the pollutant concentration (SO_2 or particulates) in micrograms per cubic meter.

The block of data cards described in Table E.3-2 would follow the //GØFT05F002 DD * card in the JCL (Figure E.3-1). Corresponding data decks would follow FT05F003 DD *, FT05F004 DD *, etc. However, no data cards are to follow FT05F005 DD DUMMY.

3.4 OUTPUT AND PROGRAM LISTINGS

The principal output of the Interface Module is the CTPC data deck, containing NCT cards. Table E.3-3 lists the data formats for these cards, a single title card is also output. The parameters in Table E.3-3 are as follows: I is a census tract sequence number (for user convenience only), IPJ is the political jurisdiction number, ICT is the census tract number, ISCT is the sub-census tract number and PC is the census tract pollutant concentration value (CTPC).

In addition to the punched card output, CØNVRT produces printed listings of the receptor point pollutant concentration (RPPC) input data corresponding to Table E.3-2 and the CTPC output data corresponding to Table E.3-3. Sample printed outputs for the NCIAQCR demonstration using the EXISTING SO_2 conditions are shown in Figures E.3-4 and E.3-5. Complete program listings of the DRIVER, CØNVRT subprogram and subroutine ORDER are given in Figures E.3-6 and E.3-7.

Table E.3-3.

Census Tract Pollutant Concentration Output Data Formats

	<u>Parameter</u>	<u>Column Position</u>	<u>Format</u>
CARD 1	TITLE	1-80	20A4
	-centered title information, one card per region		
NCT cards	CARD 2		
	I	1-5	I5
	IPJ	6-10	I5
	ICT	11-15	I5
	ISCT	16	I1
	(BLANK)	17-20	4X
	PC	21-30	F10.3

RECEPTOR POINT POLLUTANT CONCENTRATIONS -- INPUT			
WASHINGTON, D.C., EXISTING -- SULFUR DIOXIDE			
NUMBER	X-COORDINATE (KILOMETERS)	Y-COORDINATE (KILOMETERS)	POLLUTANT CONCENTRATION (MICROGRAMS PER CUBIC METER)
1	250.00	4265.00	20.23
2	250.00	4280.00	20.26
3	250.00	4295.00	20.33
4	250.00	4310.00	20.37
5	250.00	4325.00	20.29
6	250.00	4340.00	20.28
7	250.00	4355.00	20.21
8	265.00	4265.00	20.48
9	265.00	4280.00	20.46
10	265.00	4295.00	20.60
11	265.00	4310.00	20.72
12	265.00	4325.00	20.70
13	265.00	4340.00	20.62
14	265.00	4355.00	20.45
15	280.00	4265.00	20.98
16	280.00	4280.00	20.98
17	280.00	4295.00	21.25
18	280.00	4310.00	21.39
19	280.00	4325.00	21.32
20	280.00	4340.00	21.15
21	280.00	4355.00	21.13
22	295.00	4265.00	22.43
23	295.00	4280.00	22.56
24	295.00	4295.00	22.76
25	295.00	4310.00	22.79
26	295.00	4325.00	23.89
27	295.00	4340.00	22.25
28	295.00	4355.00	22.08
29	310.00	4265.00	22.67
30	310.00	4280.00	24.43
31	310.00	4295.00	26.88
32	310.00	4310.00	27.32
33	310.00	4325.00	25.45
34	310.00	4340.00	24.14
35	310.00	4355.00	22.93
36	325.00	4265.00	22.75
37	325.00	4280.00	25.14
38	325.00	4295.00	42.43
39	325.00	4310.00	79.27
40	325.00	4325.00	38.44
41	325.00	4340.00	27.83
42	325.00	4355.00	24.99
43	340.00	4265.00	23.33
44	340.00	4280.00	26.51
45	340.00	4295.00	29.48
46	340.00	4310.00	29.58
47	340.00	4325.00	31.95
48	340.00	4340.00	30.11
49	340.00	4355.00	28.47

Figure E.3-4. Printed Input RPPC Data Summary, CONVRT

CENSUS TRACT POLLUTANT CONCENTRATIONS -- OUTPUT			
WASHINGTON, D.C., EXISTING -- SULFUR DIOXIDE			
BACKGROUND = 20.00 (MICROGRAMS PER CUBIC METER)			
NUMBER	POLITICAL JURISDICTION	CENSUS TRACT	POLLUTANT CONCENTRATION (MICROGRAMS PER CUBIC METER)
1	1	1	64.78
2	1	2	61.08
3	1	3	61.08
4	1	4	63.34
5	1	5	65.39
6	1	6	56.88
7	1	7	58.98
8	1	8	56.65
9	1	9	54.08
10	1	10	56.88
11	1	11	51.77
12	1	12	56.88
13	1	13	61.40
14	1	14	58.58
15	1	15	55.22
16	1	16	63.78
17	1	17	71.15
18	1	18	70.50
19	1	19	74.51
20	1	20	71.02
21	1	21	78.91
22	1	22	78.91
23	1	23.1	83.31
24	1	23.2	89.34
25	1	24	83.31
26	1	25	71.55
27	1	26	71.55
28	1	27	71.80
29	1	28	71.82
30	1	29	71.80
31	1	30	71.82
32	1	31	79.56
33	1	32	79.56
34	1	33	86.73
35	1	34	83.56
36	1	35	81.67
37	1	36	72.06
38	1	37	71.80
39	1	38	71.80
40	1	39	68.23
41	1	40	68.23
42	1	41	66.57
43	1	42	72.06
44	1	43	72.06
45	1	44	72.06
46	1	45	72.06
47	1	46	86.73
48	1	47	63.00

Figure E.3-5. Printed Output CTPC Data Summary, CONVRT


```

FORTRAN IV G LEVEL 19          CONVRT          DATE = 71169          06/17/20
0001      SUBROUTINE CONVRT (LIN,LOUT,LIO,NCT,NRP,M,N,JPJ,JCT,JSCT,RPPC,
          1      CTPC,IDCT)
          C
          C .....
          C * TITLE: CONVRT
          C *
          C * AUTHOR: B. GOLDSTEIN
          C *
          C * TRM SYSTEMS GROUP
          C * WASHINGTON OPERATIONS
          C *
          C * COMPUTER SYSTEM: IBM SYSTEM 360/MODEL 50
          C *
          C * LANGUAGE USED: FORTRAN IV - G LEVEL
          C *
          C * ABSTRACT: TO CONVERT RECEPTOR POINT POLLUTANT
          C * CONCENTRATIONS (RPPC) TO CENSUS TRACT
          C * POLLUTANT CONCENTRATIONS (CTPC).
          C .....
          C
0002      DIMENSION TITLE(20),M(6,NCT),N(NCT),JPJ(NCT),JCT(NCT),JSCT(NCT),
          1      RPPC(NRP),CTPC(NCT),IDCT(NCT)
          C
0003      KCT=0
          C
0004      DO 10 I=1,NCT
          C
0005      READ(LIN,1100,END=20) JPJ(I),JCT(I),JSCT(I),NN,(M(I,L),L=1,NN)
          C
0006      N(I)=NN
          C
0007      KCT=KCT+1
          C
0008      10 CONTINUE
          C
0009      20 CONTINUE
          C
0010      30 CONTINUE
          C
          C
0011      READ(LIN,1200,END=120,ERR=120) TITLE
          C
0012      READ(LIN,1300) BACKGR
          C
0013      WRITE(LOUT,2100) TITLE
          C
0014      ICOUNT=0

```

Figure E.3-6. CONVRT Subprogram, Interface Module-Program Listing

PORTMAN IV G LEVEL	19	CONVRT	DATE = 7/1/69	04/17/20
0015	C	DO 50 I=1,NRP		
0016	C	HEADLIN,1400,END=40) X,Y,PC		
0017	C	RPPC(I)=PC		
0018	C	IF(IICOUNT.LT.49) GO TO 40		
0019	C	WRITE(LOUT,2100) TITLE		
0020	C	ICOUNT=0		
0021	C	40 CONTINUE		
0022	C	ICOUNT=ICOUNT+1		
0023	C	WRITE(LOUT,2200) I,X,Y,PC		
0024	C	50 CONTINUE		
0025	C	60 CONTINUE		
0026	C	DO 80 I=1,KCT		
0027	C	SUM=0.0		
0028	C	ADD=0.0		
0029	C	NN=N(I)		
0030	C	DO 70 L=1,NN		
0031	C	SUM=SUM+RPPC(NEL,I)		
0032	C	ADD=ADD+1.0		
0033	C	70 CONTINUE		
0034	C	PC=SUM/ADD+BACKGR		
0035	C	CTPC(I)=PC		
0036	C	IDCT(I)=JPJ(I)*10000+JCT(I)*10+JSCT(I)		
0037	C	80 CONTINUE		
0038	C	CALL ORDER (KCT,IDCT,CTPC)		

Figure E.3-6. CONVRT Subprogram, Interface Module-Program Listing (Cont'd)

FORTRAN IV G LEVEL 19		CONVRT	DATE = 71169	06/17/26
0039		WRITE(LOUT,2300) TITLE,BACKGR		
0040	C	WRITE(LIO,1200) TITLE		
0041	C	ICOUNT=0		
0042	C	DO 110 I=1,KCT		
0043	C	IF(ICOUNT.LT.48) GO TO 90		
0044	C	WRITE(LOUT,2300) TITLE,BACKGR		
0045	C	ICOUNT=0		
0046	C	90 CONTINUE		
0047	C	ICOUNT=ICOUNT+1		
0048	C	PC=CTPC(I)		
0049	C	ID=IDCT(I)		
0050	C	IPJ=ID/10000		
0051	C	ID=ID-IPJ*10000		
0052	C	ICT=ID/10		
0053	C	ISCT=ID-ICT*10		
0054	C	WRITE(LIO,2400) I,IPJ,ICT,ISCT,PC		
0055	C	IF(ISCT.EQ.0) GO TO 100		
0056	C	WRITE(LOUT,2500) I,IPJ,ICT,ISCT,PC		
0057	C	GO TO 110		
0058	C	100 CONTINUE		
0059	C	WRITE(LOUT,2600) I,IPJ,ICT,PC		
0060	C	110 CONTINUE		
0061	C	GO TO 30		
0062	C	120 CONTINUE		
0063	C	RETURN		

Figure E.3-6. CONVRT Subprogram, Interface Module-Program Listing (Cont'd)

```

ORTRAY IV G LEVEL 19          CONVRT          DATE = 71169          06/17/26

C
0064      C 1100 FORMAT(1X,12,1X,13,11,1X,11,615)
C
0065      C 1200 FORMAT(20A4)
C
0066      C 1300 FORMAT(F5.2)
C
0067      C 1400 FURMAT(2P2F8.0,F10.0)
C
0068      C 2100 FORMAT('1',41X,
1          'RECEPTOR POINT POLLUTANT CONCENTRATIONS -- INPUT'//
2          27X,20A4//
3          26X,'NUMBER',11X,'X-COORDINATE',11X,'Y-COORDINATE',4X,
4          'POLLUTANT CONCENTRATION'//
5          32X,2(11X,'(KILOMETERS)'),2X,
6          '(MICROGRAMS PER CUBIC METER)')//
C
0069      C 2200 FORMAT(26X,14,14X,F8.2,15X,F8.2,11X,F10.2)
C
0070      C 2300 FURMAT('1',41X,
1          'CENSUS TRACT POLLUTANT CONCENTRATIONS -- OUTPUT'//
2          27X,20A4//
3          43X,'BACKGROUND =',F6.2,' (MICROGRAMS PER CUBIC METER)'//
4          29X,'NUMBER',10X,'POLITICAL',11X,'CENSUS',7X,
5          'POLLUTANT CONCENTRATION'//
6          44X,'JURISDICTION',9X,'TRACT',6X,
7          '(MICROGRAMS PER CUBIC METER)')//
C
0071      C 2400 FORMAT(315,11,4X,F10.3)
C
0072      C 2500 FORMAT(29X,14,16X,12,14X,14,'.',11,11X,F10.2)
C
0073      C 2600 FURMAT(29X,14,16X,12,14X,14,13X,F10.2)
C
0074      C      END

```

Figure E.3-6. CONVRT Subprogram, Interface Module-Program Listing (Cont'd)

FORTRAN IV G LEVEL 19		ORDER	DATE = 71134	06/33/43
0001	SUBROUTINE ORDER (N,IA,A)			
	C	*****		
	C	* TITLE: ORDER *		
	C	* AUTHOR: H. GOLUSTEIN *		
	C	* TRW SYSTEMS GROUP *		
	C	* WASHINGTON OPERATIONS *		
	C	* COMPUTER SYSTEM: IBM SYSTEM 360/MODEL 55 *		
	C	* LANGUAGE USED: FORTRAN IV - G LEVEL *		
	C	* ABSTRACT: THIS ROUTINE SORTS, IN ASCENDING ORDER, *		
	C	* THE "N" ELEMENTS OF THE "IA" ARRAY. *		
	C	*****		
0002	C	DIMENSION IA(N),A(N)		
0003	C	L=N-1		
0004	C	DO 20 J=1,L		
0005	C	K=J+1		
0006	C	DO 10 I=K,N		
0007	C	IF (IA(I).GE. IA(J)) GO TO 10		
0008	C	IR=IA(I)		
0009	C	IA(I)=IA(J)		
0010	C	IA(J)=IR		
0011	C	B=A(I)		
0012	C	A(I)=A(J)		
0013	C	A(J)=B		
0014	C	10 CONTINUE		
0015	C	20 CONTINUE		
0016	C	RETURN		
0017	C	END		

Figure E.3-7. Subroutine ORDER, Interface Module-Program Listing

4.0 DAMAGE COSTS MODULE

4.1 DESCRIPTION

The Damage Costs Module (DAMAGE) is the principal analysis module currently incorporated into the Cost/Benefit Model. DAMAGE (see Chapter 2, Section 2.4) uses a linear equation to calculate annual damage costs on a per capita basis as a function of the pollutant concentration. A separate relation is used for particulates and sulfur oxides; the specific slope and intercept values for the damage equation are supplied by the user as input data. Without loss of generality, the EXISTING-SO₂ data for the NCIAQCR demonstration will be used for illustrative purposes throughout this section.

All of the analysis modules have certain features of program design in common. The main programs or DRIVER programs contain the only dimension statements which must be changed by the user to fit the requirements of his particular study. The dimension statements requiring change are all indicated by an asterisk in column 80. All of the I/O devices are set in the DRIVER. Some of these can be "dummied out" through the JCL to eliminate certain output.

The input data sets are coded as follows:

- Data Set 1 - always contains specific operational parameters required by the program, e.g., slope and intercept of damage function.
- Data Set 2 - is always the census tract attribute data deck.
- Data Set 3 - is always an SO₂ air quality data deck.
- Data Set 4 - is always a particulate air quality data deck.

The output data sets are coded in a similar fashion:

- Data Set 11 - always provides title page information and census data (input) summaries.

- Data Set 12 - always provides CTPC data (input) summaries
- Data Set 13 - always provides the principal output of the module.

Data sets 11 and 12 provide optional output. The procedure for eliminating them is described in Section 4.2 for the Damage Costs Module. However, the procedure applies to all analysis modules.

4.2 JOB CONTROL LANGUAGE AND DECK SET-UP

Figure E.4-1 illustrates the JCL and deck set-up for the Damage Costs Module. The order follows: source and/or object decks first, output data set specification, then input data set specification. The input data is ordered: damage function, slope and intercept, census tract attribute data deck, then census tract air quality data deck from CØNVRT (SO₂ or particulates).

Any of the output categories described in the previous subsection can be suppressed or "dummied out" through the JCL specifying the output data set. For example to eliminate Data Set 11, substitute:

```
//GØ.FT11F001 DD DUMMY
```

for the JCL statement*:

```
//GØ.FT11F001 DD SYSØUT=A,DCB=(RECFM=UA,LRECL=133,BLKSIZE=133).
```

Figure E.4-1 illustrates the set-up and JCL for processing an SO₂ census tract air quality deck. Notice that in this case, Data Set 4 which has been reserved for particulate air quality data in the program has been dummied out by an analogous procedure to the one just described. In order to process a particulate census tract air quality deck, the last part of the job deck would appear as follows:

* "SYSØUT=A", sets the corresponding output data set to the printer.

```

JOB SETUP FOR DAMAGE MODEL

//DAMAGE EXEC PROC=FCRTGCLG
//FORT.SYSIN DD *

SOURCE DECKS

/*
//LKED.SYSIN DD *

OBJECT DECKS

/*
//GO.FT11F001 DD SYSOUT=A,DCB=(RECFM=UA,LRECL=133,BLKSIZE=133)
//GO.FT12F001 DD SYSOUT=A,DCB=(RECFM=UA,LRECL=133,BLKSIZE=133)
//GO.FT13F001 DD SYSOUT=A,DCB=(RECFM=UA,LRECL=133,BLKSIZE=133)
//GO.FT01F001 DD *

DAMAGE FUNCTION SLOPE AND INTERCEPT - SO2

/*
//GO.FT02F001 DD *

CENSUS TRACT ATTRIBUTE DATA DECK

/*
//GO.FT03F001 DD *

AIR QUALITY DATA DECK - SO2

/*
//GO.FT04F001 DD DUMMY
/*

```

Figure E.4-1. Job Control Language and Deck Set-Up for Damage Costs Module (DAMAGE)

```
//GØ.FT03F001 DD DUMMY
/*
//GØ.FT04F001 DD *
      Air Quality Data Deck - particulates
/*
```

4.3 DIMENSIONS AND INPUT DATA FORMATS

The only variable dimension in the DRIVER is NCT, which in this case (and for all existing analysis modules) is the number of census tracts. For the NCIAQCR demonstration, NCT=366. So in the program listings shown here:

NCT/366/.

The I/O data sets are set as follows:

- LIN1/1/-Input data set, i.e., card reader - damage function slope and intercept.
- LIN2/2/-Input data set, i.e., card reader - census tract attribute data deck.
- LIN3/3/-Input data set, i.e., card reader - air quality data deck, SO₂ or DUMMY.
- LIN4/4/-Input data set, i.e., card reader-air quality data deck, particulate or DUMMY.
- LØUT1/11/-Output data set, i.e., printer-title page and census tract attributes as input.
- LØUT2/12/-Output data set, i.e., printer-census tract pollutant concentrations as input.
- LØUT3/13/-Output data set, i.e., printer-census tract damage costs with regional and political jurisdiction summaries.

The slope and intercept values for the damage equation are provided on a single punched card. The format is shown in Table E.4-1. The census tract attribute data deck has been described in Section 2 of this appendix. However, DAMAGE doesn't read into core all of the attributes shown in Table E.2-1. Table E.4-2 shows these card formats again, with the fields not read by DAMAGE indicated by the notation, "(SKIP)". The formats for the census tract pollutant concentration data cards have been given previously in Table E.3-3. The CTPC data deck was previously produced by CONVRT. Table E.4-3 shows these CTPC data formats again, however, using notation after the program code in DAMAGE.

Table E.4-1.

Damage Function Slope and Intercept, Input Data Format
- Damage Costs Module

<u>Parameter</u>	<u>Columns</u>	<u>Format</u>
A (slope)	1-10	F10.3
B (intercept)	11-20	F10.3

Table E.4-2.

Census Tract Attributes As Read By DAMAGE

	<u>Parameter</u>	<u>Columns</u>	<u>Format</u>
NCT Cards (2 cards per census tract)	<u>CARD 1</u>		
	TITLE1	1-80	20A4
	-left justified title information beginning in column three		
	<u>CARD 2</u>		
	KCT	1-9	2A4,A1
	(SKIP)	10-22	13X
	PØP	23-30	F8.2
	<u>CARD 3</u>		
	(SKIP)	1-80	80X

Table E.4-3.

Census Tract Air Quality Data Formats For
SO₂ or Particulates, Damage Costs Module

	<u>Parameter</u>	<u>Columns</u>	<u>Format</u>
NCT Cards	<u>CARD 1</u>		
	TITLE2	1-80	20A4
	- centered title information		
	<u>CARD 2</u>		
	J	1-5	I5
	JPJ	6-10	I5
	JCT	11-15	I5
	JSCT	16	I1
	(BLANK)	17-20	4X
	AQ	21-30	F10.3

4.4 OUTPUT AND PROGRAM LISTINGS

The sample outputs from DAMAGE for the case of EXISTING-SO₂ air quality data for the NCIAQCR demonstration are shown in Figures E.4-2 E.4-3, and E.4-4. These correspond to data sets 11(LØUT1), 12(LØUT2) and 13(LØUT3), respectively.

The program listing for the DRIVER portion of the Damage Costs Module is given in Figure E.4-5. The listing for the DAMAGE subprogram is given in Figure E.4-6.

GENERAL PURPOSE, LINEAR DAMAGE FUNCTION	
DAMAGE PER CAPITA = (0.640) X AIR QUALITY + (-5.900)	

CENSUS TRACT ATTRIBUTES -- INPUT	
WASHINGTON, D.C.	
CENSUS TRACT NUMBER	TOTAL POPULATION
0001	5963.
0002	5723.
0003	6412.
0004	1280.
0005	7285.
0006	5486.
0007	8544.
0008	6235.
0009	6715.
0010	11696.
0011	5203.
0012	5213.
0013	7803.
0014	6549.
0015	6177.
0016	5458.
0017	5872.
0018	9284.
0019	8536.
0020	7525.
0021	13753.
0022	9471.
0023001	4416.
0023002	2134.
0024	5497.
0025	9210.
0026	2732.
0027	1155.
0028	

Figure E.4-2. Sample Output From Damage Costs Module, Title Page and Census Tract Attributes as Input.

CENSUS TRACT POLLUTANT CONCENTRATIONS -- INPUT			
WASHINGTON, D.C., EXISTING -- SULFUR DIOXIDE			
NUMBER	POLITICAL JURISDICTION	CENSUS TRACT	POLLUTANT CONCENTRATION (MICROGRAMS PER CUBIC METER)
1	1	1	64.78
2	1	2	61.08
3	1	3	61.08
4	1	4	63.34
5	1	5	65.39
6	1	6	56.88
7	1	7	58.98
8	1	8	56.65
9	1	9	54.08
10	1	10	56.88
11	1	11	51.77
12	1	12	56.88
13	1	13	61.40
14	1	14	58.58
15	1	15	55.22
16	1	16	63.78
17	1	17	71.15
18	1	18	70.50
19	1	19	74.51
20	1	20	71.02
21	1	21	78.91
22	1	22	78.91
23	1	23.1	83.31
24	1	23.2	89.34
25	1	24	83.31
26	1	25	71.55
27	1	26	71.55
28	1	27	71.80
29	1	28	71.80
30	1	29	71.80
31	1	30	71.80
32	1	31	79.56
33	1	32	79.56
34	1	33	86.73
35	1	34	83.56
36	1	35	81.67
37	1	36	72.06
38	1	37	71.80
39	1	38	71.80
40	1	39	68.23
41	1	40	68.23
42	1	41	66.57
43	1	42	72.06
44	1	43	72.06
45	1	44	72.06
46	1	45	72.06
47	1	46	86.73
48	1	47	83.00
49	1	48	86.73

Figure E. 4-3. Sample Output From Damage Cost Module, Census Tract Pollutant Concentrations As Input.

CENSUS TRACT DAMAGE COST				
WASHINGTON, D.C., EXISTING -- SULFUR DIOXIDE				
NUMBER	POLITICAL JURISDICTION	CENSUS TRACT	EXPOSURE	DAMAGE COST
324	5	26	185797.	98909.
325	5	27	232448.	124273.
326	5	28	208235.	111328.
327	5	29	248271.	132194.
328	5	30	254824.	134796.
329	5	31	251868.	133702.
330	5	32	227776.	120613.
331	5	33	552622.	277226.
332	5	34	160903.	85782.
333	5	35	607554.	320812.
334	5	36	180097.	94668.
335	5	37	271203.	145304.
336	5	38	383478.	209227.
337	5	39	403500.	216000.
338	5	40	282928.	151912.
339	5	41	206058.	108635.
340	5	42	178903.	93191.
341	5	43	108656.	57795.
342	5	44	156264.	81589.
343	5	45	83247.	43375.
45	POLITICAL JURISDICTION TOTALS		12544913.	6731982.
	POLITICAL JURISDICTION AVERAGES		278776.	144600.
	POLITICAL JURISDICTION AIR QUALITY		47.82	(WEIGHTED W.R.T. POPULATION)
344	6	1	138313.	75245.
345	6	2	121194.	66386.
346	6	3	181645.	99184.
347	6	4	20184.	10832.
348	6	5	323459.	176620.
349	6	6	193457.	105634.
350	6	7	135822.	74581.
351	6	8	340450.	186712.
352	6	9	303042.	168438.
353	6	10	245716.	137717.
354	6	11	389754.	218446.
355	6	12	523013.	295029.
356	6	13	250777.	136341.
357	6	14	257125.	139793.
358	6	15	242752.	133689.
359	6	16	263378.	141493.
360	6	17	56798.	31432.
361	6	18	342126.	187932.
362	6	19	146136.	77454.
363	6	20	421781.	231987.
20	POLITICAL JURISDICTION TOTALS		4896983.	2695037.
	POLITICAL JURISDICTION AVERAGES		244849.	134752.
	POLITICAL JURISDICTION AIR QUALITY		53.81	(WEIGHTED W.R.T. POPULATION)
364	7	1	113179.	60612.
365	7	2	270555.	144538.
366	7	3	98520.	53020.
3	POLITICAL JURISDICTION TOTALS		482254.	258169.
	POLITICAL JURISDICTION AVERAGES		160751.	86056.
	POLITICAL JURISDICTION AIR QUALITY		47.33	(WEIGHTED W.R.T. POPULATION)
366	REGIONAL TOTALS		129200000.	73551808.
	REGIONAL AVERAGES		353005.	200961.
	REGIONAL AIR QUALITY		65.05	(WEIGHTED W.R.T. POPULATION)

Figure E.4-4. Sample Output From Damage Costs Module, Census Tract Damage Cost Summary.

FORTRAN IV G LEVEL 19		MAIN	DATE = 71134	08/34/05
	C	DRIVER FOR DAMAGE FUNCTION ROUTINE		
	C			
	C			
0001		DATA LIN1/1/,LIN2/2/,LIN3/3/,LIN4/4/,		*
	1	LOUT1/11/,LOUT2/12/,LOUT3/13/,		*
	2	NCT/366/		*
	C			
0002		CALL DAMAGE (LIN1,LIN2,LIN3,LIN4,LOUT1,LOUT2,LOUT3,NCT)		
	C			
0003		STOP		
	C			
0004		END		

Figure E.4-5. Program Listing for DRIVER
Main Program-Damage Costs Module.

```

FORTRAN IV G LEVEL 19          DAMAGE          DATE = 71135          10/11/38
0001      SUBROUTINE DAMAGE (LIN1,LIN2,LIN3,LIN4,LOUT1,LOUT2,LOUT3,NCT)
C
C *****
C *
C * TITLE:  DAMAGE
C *
C * AUTHOR:  B. GOLDSTEIN
C *
C * TRW SYSTEMS GROUP
C * WASHINGTON OPERATIONS
C *
C * COMPUTER SYSTEM:  IBM SYSTEM 360/MODEL 50
C *
C * LANGUAGE USED:  FORTRAN IV - G LEVEL
C *
C * ABSTRACT:  THIS ROUTINE WILL GENERATE DAMAGE COSTS
C *            BY USING A GENERAL PURPOSE, LINEAR
C *            DAMAGE FUNCTION.
C *
C *****
C
0002      DIMENSION TITLE1(20),TITLE2(20),KCT(3)
0003      DIMENSION PJ(6),SR(2),T1(2),T2(3),T3(3),WA(7)
0004      DATA PJ/' PO','LIT','CAL ','JUR','SDIC','TION'/,
1          SR/'REGI','ONAL'/,
2          T1/' TOT','ALS '/,
3          T2/' AVE','RAGE','S '/,
4          T3/' AIR','QUA','LITY'/,
5          WA/'WEI','GHTE','D W.','R.T.',' POP','ULAT','ION'/
C
C DAMAGE FUNCTION:
C
C DC/C = A X (CTAQ) + B
C
C WHERE DC/C -- DAMAGE COST PER CAPITA
C          CTAQ -- CENSUS TRACT AIR QUALITY
C
C CTDC = (DC/C) X (CTP)
C
C WHERE CTDC -- CENSUS TRACT DAMAGE COST
C          DC/C -- DAMAGE COST PER CAPITA
C          CTP -- CENSUS TRACT POPULATION
C
0005      READ(LIN1,1100) A,B
C

```

Figure E.4-6. Program Listing for DAMAGE Subprogram-Damage Costs Module

FORTRAN IV G LEVEL 19		DAMAGE	DATE = 71135	10/11/38
0006		WRITE(LOUT1,2100) A,B		
0007	C	READ(LIN2,1200) TITLE1		
0008	C	WRITE(LOUT1,2200) TITLE1		
0009	C	ICONT1=0		
0010	C	READ(LIN3,1200,END=101) TITLE2		
0011	C	LIN=LIN3		
0012	C	GO TO 20		
0013	C	10 CONTINUE		
0014	C	READ(LIN4,1200,END=130) TITLE2		
0015	C	LIN=LIN4		
0016	C	20 CONTINUE		
0017	C	WRITE(LOUT2,2300) TITLE2		
0018	C	ICONT2=0		
0019	C	WRITE(LOUT3,2400) TITLE2		
0020	C	ICONT3=0		
0021	C	IPJ=1		
0022		SCF=0.0		
0023		TCT=0.0		
0024		SPDP=0.0		
0025		TPDP=0.0		
0026		SPOSE=0.0		
0027		TPOSE=0.0		
0028		SD=0.0		
0029		TN=0.0		
0030	C	DO 110 I=1,NCT		
0031	C	READ(LIN2,1300) KCT,PDP		

Figure E.4-6. Program Listing for DAMAGE Subprogram-Damage Costs Module (Cont'd)

FORTRAN IV G LEVEL 19		DAMAGE	DATE = 71135	10/11/38
0032		IF(ICONT1.LT.50) GO TO 30		
0033	C	WRITE(LOUT1,2200) TITLE1		
0034	C	ICONT1=0		
0035	C	30 CONTINUE		
0036	C	ICONT1=ICONT1+1		
0037	C	WRITE(LOUT1,2500) KCT,PDP		
0038	C	READ(LIN,1400) J,JPJ,JCT,JSCT,AQ		
0039	C	IF(ICONT2.LT.49) GO TO 40		
0040	C	WRITE(LOUT2,2300) TITLE2		
0041	C	ICONT2=0		
0042	C	40 CONTINUE		
0043	C	ICONT2=ICONT2+1		
0044	C	IF(JSCT.EQ.0) GO TO 50		
0045	C	WRITE(LOUT2,2610) J,JPJ,JCT,JSCT,AQ		
0046	C	GO TO 60		
0047	C	50 CONTINUE		
0048	C	WRITE(LOUT2,2620) J,JPJ,JCT,AQ		
0049	C	60 CONTINUE		
0050	C	IF(JPJ.EQ.(PJ)) GO TO 80		
0051	C	IF(ICONT3.LT.46) GO TO 70		
0052	C	WRITE(LOUT3,2400) TITLE2		
0053	C	ICONT3=0		
0054	C	70 CONTINUE		
0055	C	ICONT3=ICONT3+5		
0056	C	HCT=IFIX(JSCT+0.01)		

Figure E.4-6. Program Listing for DAMAGE Subprogram-Damage Costs Module (Cont'd)

FORTRAN IV G LEVEL 19		DAMAGE	DATE = 7/1/35	10/11/38
0057		WRITE(LOUT3,2710) MCT,PJ,T1,SPOSE,SD		
0058	C	APOSE=SPOSE/SCT		
0059	C	AD=SD/SCT		
0060	C	WRITE(LOUT3,2720) PJ,T2,APOSE,AD		
0061	C	APOSE=SPOSE/SPDP		
0062	C	WRITE(LOUT3,2730) PJ,T3,APOSE,WA		
0063	C	IPJ=JPJ		
0064	C	SCT=Q.0		
0065	C	SPDP=Q.0		
0066	C	SPOSE=Q.0		
0067	C	SD=Q.0		
0068	C	80 CONTINUE		
0069	C	IF(POP.LE.0.0) GO TO 110		
0070	C	POSE=AQ*POP		
0071	C	D=(A*AQ+B)*POP		
0072	C	SCT=SCT+1.0		
0073	C	TCT=TCT+1.0		
0074	C	SPDP=SPDP+POP		
0075	C	TPOP=TPOP+POP		
0076	C	SPOSE=SPOSE+POSE		
0077	C	TPOSE=TPOSE+POSE		
0078	C	SD=SD+D		
0079	C	TD=TD+D		
0080	C	IF(ICONT3.LT.49) GO TO 90		
0081	C	WRITE(LOUT3,2400) TITLE2		
0082	C	ICONT3=0		

Figure E.4-6. Program Listing for DAMAGE Subprogram-Damage Costs Module (Cont'd)

FORTRAN IV G LEVEL 19		DAMAGE	DATE = 71135	10/11/38
0083	C	90 CONTINUE		
0084	C	ICONT3=ICONT3+1		
0085	C	IF(JSCT.EQ.0) GO TO 100		
0086	C	WRITE(LOUT3,2810) I,JPJ,JCT,JSCT,POSE,D		
0087	C	GO TO 110		
0088	C	100 CONTINUE		
0089	C	WRITE(LOUT3,2820) I,JPJ,JCT,POSE,D		
0090	C	110 CONTINUE		
0091	C	IF(ICONT3.LT.46) GO TO 120		
0092	C	WRITE(LOUT3,2400) TITLE2		
0093	C	ICONT3=0		
0094	C	120 CONTINUE		
0095	C	ICONT3=ICONT3+5		
0096	C	MCT=IFIX(SCT+0.01)		
0097	C	WRITE(LOUT3,2710) MCT,PJ,T1,SPOSE,SD		
0098	C	APOSE=SPOSE/SCT		
0099	C	AD=SD/SCT		
0100	C	WRITE(LOUT3,2720) PJ,T2,APOSE,AD		
0101	C	APOSE=SPOSE/SPQP		
0102	C	WRITE(LOUT3,2730) PJ,T3,APOSE,WA		
0103	C	IF(ICONT3.GT.45) WRITE(LOUT3,2400) TITLE2		
0104	C	MCT=IFIX(TCT+0.01)		
0105	C	WRITE(LOUT3,2910) MCT,SR,T1,TPOSE,TD		
0106	C	APOSE=TPOSE/TCT		
0107	C	AD=TD/TCT		

Figure E.4-6. Program Listing for DAMAGE Subprogram-Damage Costs Module
(Cont'd)

FORTRAN IV G-LEVEL	19	DAMAGE	DATE = 7/1/35	10/11/38
0108	C	WRITE(LOUT3,2920) SR,T2,APOSE,AD		
0109	C	APOSE=TPOSE/TPOP		
0110	C	WRITE(LOUT3,2930) SR,T3,APOSE,WA		
0111	C	130 CONTINUE		
0112	C	RETURN		
0113	C	1100 FORMAT(2F10.3)		
0114	C	1200 FORMAT(20A4)		
0115	C	1300 FORMAT(2A4,A1,13X,F8.2/ROX)		
0116	C	1400 FORMAT(315,11.4X,F10.3)		
0117	C	2100 FORMAT('1',46X,'GENERAL PURPOSE, LINEAR DAMAGE FUNCTION'///////// 1 38X,'DAMAGE PER CAPITA = ('F8.3,') X AIR QUALITY + ('F8.3,')') 2		
0118	C	2200 FORMAT('1',49X,'CENSUS TRACT ATTRIBUTES -- INPUT'///41X,20A4// 1 45X,'CENSUS TRACT NUMBER',8X,'TOTAL POPULATION'/)		
0119	C	2300 FORMAT('1',42X,'CENSUS TRACT POLLUTANT CONCENTRATIONS -- INPUT' 1 //27X,20A4// 2 42X,'NUMBER',4X,'POLITICAL',5X,'CENSUS', 3 5X,'POLLUTANT CONCENTRATION'/ 4 51X,'JURISDICTION',3X,'TRACT', 5 4X,'(MICROGRAMS PER CUBIC METER)'/)		
0120	C	2400 FORMAT('1',54X,'CENSUS TRACT DAMAGE COST'///27X,20A4// 1 31X,'NUMBER',6X,'POLITICAL',7X,'CENSUS',12X,'EXPOSURE', 2 12X,'DAMAGE'/42X,'JURISDICTION',5X,'TRACT',34X,'COST'/)		
0121	C	2500 FORMAT(49X,2A4,A1,F25.0)		
0122	C	2610 FORMAT(1X,I45,I12,I12,'.',I1,F19.2)		
0123	C	2620 FORMAT(1X,I45,I12,I12,F21.2)		
0124	C	2710 FORMAT('0',I34,4X,6A4,2A4,F14.0,F19.0)		
0125	C	2720 FORMAT(39X,6A4,3A4,F10.0,F19.0)		
0126	C	2730 FORMAT(39X,6A4,3A4,F12.2,6X,7A4/)		

Figure E.4-6. Program Listing for DAMAGE Subprogram-Damage Costs Module (Cont'd)

FORTRAN IV G LEVEL 19		DAMAGE	DATE = 71135	10/11/38
	C			
0127	2810	FORMAT(1X,I34,I14,I14,'.',I1,F20.0,F19.0)		
	C			
0128	2820	FORMAT(1X,I34,I14,I14,F22.0,F19.0)		
	C			
0129	2910	FORMAT('0',I34,6X,2A4,2A4,F28.0,F19.0)		
	C			
0130	2920	FORMAT(41X,2A4,3A4,F24.0,F19.0)		
	C			
0131	2930	FORMAT(41X,2A4,3A4,F26.2,6X,7A4)		
	C			
0132		END		

Figure E.4-6. Program Listing for DAMAGE Subprogram-Damage Costs Module
(Cont'd)

5.0 PROPERTY VALUE MODULE

5.1 DESCRIPTION

The Property Value Module (PROP) calculates four types of residential property values using the Anderson-Crocker regression equation. The basis for the four property value types and the design principles for this module have been given in Chapter 2, Section 2.4.

PROP has many programming features in common with DAMAGE, described in Section 4 of this appendix. It is recommended that the user read the information given in that section before going further.

The major difference between DAMAGE and PROP is that PROP processes a pair (SO_2 and particulates) of census tract pollutant concentration data decks per run. DAMAGE processes either an SO_2 deck or particulate deck in any single run.

5.2 JOB CONTROL LANGUAGE AND DECK SET-UP

The JCL and deck set-up for PROP are illustrated in Figure E.5-1. The order is as follows: source and/or object decks first, output data set specifications, then input data set specifications. The input data is in the order: regression line coefficients, census tract attribute data deck, census tract air quality data deck for SO_2 , and census tract air quality data deck for particulates.


```

JOB SETUP FOR PROP MODEL

//PRJP EXEC PROC=FORTGCLG
//FJRT.SYSIN DD *

SOURCE DECKS

/*
//LKED.SYSIN DD *

OBJECT DECKS

/*
//GO.FT11F001 DD SYSOUT=A,DCB=(RECFM=UA,LRECL=133,BLKSIZE=133)
//GO.FT12F001 DD SYSOUT=A,DCB=(RECFM=UA,LRECL=133,BLKSIZE=133)
//GO.FT13F001 DD SYSOUT=A,DCB=(RECFM=UA,LRECL=133,BLKSIZE=133)
//GO.FT01F001 DD *

REGRESSION LINE COEFFICIENTS

/*
//GO.FT02F001 DD *

CENSUS TRACT ATTRIBUTE DATA DECK

/*
//GO.FT03F001 DD *

AIR QUALITY DATA DECK - SO2

/*
//GO.FT04F001 DD *

AIR QUALITY DATA DECK - PARTICULATES

/*

```

Figure E.5-1. Job Control Language and Deck Set-Up for Property Value Module.

5.3 DIMENSIONS AND INPUT DATA FORMATS

The only variable dimension in the DRIVER that must be changed by the user is NCT, the number of census tracts. For the NCIAQCR demonstration, the dimension statement is:

NCT/366/.

The input data sets are set in DRIVER as follows:

- LIN1/1/-Input data set, i.e., card reader-regression line coefficients and sulfation rate factor.
- LIN2/2/-Input data set, i.e., card reader-census tract attribute data deck.
- LIN3/3/-Input data set, i.e., card reader-census tract air quality data deck, SO₂.
- LIN4/4/-Input data set, i.e., card reader-census tract air quality data deck, particulates.

The output data sets are set in DRIVER as follows:

- LOUT1/11/-Output data set, i.e., printer-title page and census tract attributes (as input).
- LOUT2/22/-Output data set, i.e., printer-census tract pollutant concentration data for SO₂ and particulates (as input).
- LOUT3/13/-Output data set, i.e., printer-census tract property values (Types I, II, III and IV) with regional and political jurisdiction summaries.

LOUT3 is the principal output data set; the optional input data summaries of LOUT1 and LOUT2 can be suppressed through the JCL as explained in Section 4 of this appendix.

The data formats for the LIN1 (data set 1) are shown in Table E.5-1. A single punched card provides the sulfation rate factor, relating sulfation rate (milligrams per 100 square centimeters) to average sulfur dioxide concentration (parts per million). Another punched card contains a complete set of Anderson-Crocker regression coefficients in the form:

$$\begin{aligned} \text{Ln(PV)} = & \text{CONST} + A \times \text{Ln(PSN)} + B \times \text{Ln(PPT)} + C \times \text{Ln(MFI)} \\ & + D \times \text{Ln(DLP)} + E \times \text{Ln(OLD)} + F \times \text{Ln(NWT)} + G \\ & \times \text{Ln(DIS)} + H \times \text{Ln(MRM)}. \end{aligned}$$

The Anderson-Crocker equations have been discussed in Chapter 2, Section 2.5. Four coefficient cards are required for the four property values types: Type I, II, III and IV, in that order.

Table E.5-2 shows the formats for the census tract attributes data deck. The formats have previously been given in Table E.2-1. However, the notation "(SKIP)" has been employed in Table E.5-2 to indicate fields not read into core by PRØP.

Table E.5-3 shows the formats for the SO₂ census tract air quality data cards and Table E.5-4 shows the formats for the particulate census tract air quality data cards. These are the same as indicated in Table E.3-3, showing the output format for these cards from CONVRT. However, the notation employed in Tables E.5-3 and E.5-4 follows the program code.

Table E.5-1.

Sulfation Rate and Regression Coefficient Input Data
Formats, Property Value Module

	<u>Parameter</u>	<u>Columns</u>	<u>Format</u>
	<u>CARD 1</u> - one card		
	FACTØR	1-5	F5.3
	<u>CARD 2</u>		
I = 1,2,3,4 (four cards)	CØNST(I)	1-8	F8.4
	A(I)	9-16	F8.4
	B(I)	17-24	F8.4
	C(I)	25-32	F8.4
	D(I)	33-40	F8.4
	E(I)	41-48	F8.4
	F(I)	49-56	F8.4
	G(I)	57-64	F8.4
	H(I)	65-72	F8.4
	(BLANK)	73-80	8X

Table E.5-2.
Census Tract Attribute Data Formats
As Read by the Property Value and Assignment Modules

	<u>Parameter</u>	<u>Columns</u>	<u>Format</u>
NCT cards (2 cards per census tract)	<u>CARD 1</u>		
	TITLE1	1-80	20A4
	-left justified title information, beginning in column three		
	<u>CARD 2</u>		
	KCT	1-9	2A4,A1
	(BLANK)	10	1X
	Q1	11-16	F6.2
	Q2	17-22	F6.3
	PØP	23-30	F8.2
	MIL	31-38	F8.2
	SFH	39-46	F8.2
	ALL	47-54	F8.2
	ØWN	55-62	F8.2
	RENT	63-70	F8.2
	<u>CARD 3</u>		
	(SKIP)	1-10	10X
	MPV	11-18	F8.2
	MGR	19-25	F7.2
	MCR	26-32	F7.2
	Ln(MFI)	33-40	F8.3
	Ln(DLP)	41-48	F8.3
	Ln(ØLD)	49-56	F8.3
	Ln(NWT)	57-64	F8.3
	Ln(DIS)	65-72	F8.3
	Ln(MRM)	73-80	F8.4

Table E.5-3.

Census Tract Air Quality Input Data Formats for SO₂,
Property Value and Assignment Modules

	<u>Parameter</u>	<u>Columns</u>	<u>Format</u>
	<u>CARD 1</u>		
	TITLE2	1-80	20A4
	- centered title information		
	<u>CARD 2</u>		
NCT cards	J1	1-5	I5
	JPJ1	6-10	I5
	JCT1	11-15	I5
	JSCT1	16	I1
	(BLANK)	17-20	4X
	PSN	21-30	F10.3

Table E.5-4.
 Census Tract Air Quality Input Data Formats for Particulates,
 Property Value and Assignment Module

		<u>Parameter</u>	<u>Columns</u>	<u>Format</u>
<u>CARD 1</u>				
		TITLE3	1-80	20A4
		- centered title information		
<u>CARD 2</u>				
NCT Cards	{	J2	1-5	I5
		JPJ2	6-10	I5
		JCT2	11-15	I5
		JSCT2	16	I1
		(BLANK)	17-20	4X
		PPT	21-30	F10.3

5.4 OUTPUT AND PROGRAM LISTINGS

Figures E.5-2, E.5-3 and E.5-4 show sample outputs from the Property Value Module for the NCIAQCR demonstration using EXISTING SO₂ and EXISTING PARTICULATE air quality data. Figures E.5-2 and E.5-3 present the input data summaries corresponding to Data Set 11 (LØUT1) and Data Set 12 (LØUT2), respectively. The census tract property value summary corresponding to Data Set 13 (LØUT3) is shown in Figure E.5-4.

The Program Listings for DRIVER and Subprogram PRØP are given in Figures E.5-5 and E.5-6.

ANDERSON-CROCKER REGRESSION EQUATION

$$\begin{aligned} \text{LN(PV-1)} = & (3.3901) + (-0.0712 \times \text{LN(PSN)}) + (-0.0610 \times \text{LN(PPT)}) + (0.7677 \times \text{LN(MFI)}) + (0.0044 \times \text{LN(DLP)}) \\ & + (-0.0106 \times \text{LN(OLD)}) + (0.0251 \times \text{LN(NWT)}) + (-0.0582 \times \text{LN(DIS)}) + (0.0 \times \text{LN(MRM)}) \end{aligned}$$

$$\begin{aligned} \text{LN(PV-2)} = & (1.1617) + (0.0010 \times \text{LN(PSN)}) + (-0.1698 \times \text{LN(PPT)}) + (0.9970 \times \text{LN(MFI)}) + (0.0113 \times \text{LN(DLP)}) \\ & + (-0.0213 \times \text{LN(OLD)}) + (0.0321 \times \text{LN(NWT)}) + (-0.0312 \times \text{LN(DIS)}) + (0.9064 \times \text{LN(MRM)}) \end{aligned}$$

$$\begin{aligned} \text{LN(PV-3)} = & (0.2428) + (-0.0905 \times \text{LN(PSN)}) + (0.0049 \times \text{LN(PPT)}) + (0.5109 \times \text{LN(MFI)}) + (0.0121 \times \text{LN(DLP)}) \\ & + (-0.0606 \times \text{LN(OLD)}) + (-0.0043 \times \text{LN(NWT)}) + (-0.0216 \times \text{LN(DIS)}) + (0.0 \times \text{LN(MRM)}) \end{aligned}$$

$$\begin{aligned} \text{LN(PV-4)} = & (0.4705) + (-0.0727 \times \text{LN(PSN)}) + (-0.0302 \times \text{LN(PPT)}) + (0.4650 \times \text{LN(MFI)}) + (-0.0054 \times \text{LN(DLP)}) \\ & + (-0.0408 \times \text{LN(OLD)}) + (-0.0124 \times \text{LN(NWT)}) + (-0.0111 \times \text{LN(DIS)}) + (0.0 \times \text{LN(MRM)}) \end{aligned}$$

CENSUS TRACT ATTRIBUTES -- INPUT

WASHINGTON, D.C.

CENSUS TRACT NUMBER	TOTAL POPULATION	AREA IN SQUARE MILES	MEDIAN PROPERTY VALUE	MEDIAN FAMILY INCOME	DILAPIDATED HOUSING UNITS	HOUSING OVER 10 YEARS OLD	NONWHITE OCCUPIED HOUSING	DISTANCE BUSINESS DISTRICT	MEDIAN ROOMS IN HOUSING
0001	5963.	0.	0.	1.	1.	1.	1.	1.0	1.0
0002	5723.	0.	0.	1.	1.	1.	1.	1.0	1.0
0003	6412.	301.	17801.	8647.	1.	2310.	30.	4.0	5.5
0004	1280.	0.	0.	1.	1.	1.	1.	1.0	1.0
0005	7295.	0.	0.	1.	1.	1.	1.	1.0	1.0
	5486.	320.	23202.	11580.	1.	1.	1.	1.0	1.0
		237.	20000.						

Figure E.5-2. Sample Output, Title Page and Census Tract Attributes Summary from Property Value Module.

CENSUS TRACT POLLUTANT CONCENTRATIONS -- INPUT						
WASHINGTON, D.C., EXISTING -- SULFUR DIOXIDE						
NUMBER	POLITICAL JURISDICTION	CENSUS TRACT	POLLUTANT CONCENTRATION (MICROGRAMS PER CUBIC METER)	NUMBER	POLITICAL JURISDICTION	CENSUS TRACT
50	1	49	80.99	50	1	49
51	1	50	72.06	51	1	49
52	1	51	70.78	52	1	51
53	1	52	72.06	53	1	52
54	1	53	70.78	54	1	53
55	1	54	72.06	55	1	54
56	1	55	70.78	56	1	55
57	1	56	72.06	57	1	56
58	1	57	70.78	58	1	57
59	1	58	72.06	59	1	58
60	1	59	70.78	60	1	59
61	1	60	72.06	61	1	60
62	1	61	70.78	62	1	61
63	1	62	72.06	63	1	62
64	1	63	70.78	64	1	63
65	1	64	72.06	65	1	64
66	1	65	70.78	66	1	65
67	1	66	72.06	67	1	66
68	1	67	70.78	68	1	67
69	1	68	72.06	69	1	68
70	1	69	70.78	70	1	69
71	1	70	72.06	71	1	70
72	1	71	70.78	72	1	71
73	1	72	72.06	73	1	72
74	1	73	70.78	74	1	73
75	1	74	72.06	75	1	74
76	1	75	70.78	76	1	75
77	1	76	72.06	77	1	76
78	1	77	70.78	78	1	77
79	1	78	72.06	79	1	78
80	1	79	70.78	80	1	79
81	1	80	72.06	81	1	80
82	1	81	70.78	82	1	81
83	1	82	72.06	83	1	82
84	1	83	70.78	84	1	83
85	1	84	72.06	85	1	84
86	1	85	70.78	86	1	85
87	1	86	72.06	87	1	86
88	1	87	70.78	88	1	87
89	1	88	72.06	89	1	88
90	1	89	70.78	90	1	89
91	1	90	72.06	91	1	90
92	1	91	70.78	92	1	91
93	1	92	72.06	93	1	92
94	1	93	70.78	94	1	93
95	1	94	72.06	95	1	94
96	1	95	70.78	96	1	95
97	1	96	72.06	97	1	96
98	1	97	70.78	98	1	97
			103.94			100.59

Figure E.5-3. Sample Output, Census Tract Pollutant Concentrations (SO₂ and Particulates) Summary from Property Value Module.

CENSUS TRACT PROPERTY VALUE

WASHINGTON, D.C.

NUMBER	POLITICAL JURISDICTION	CENSUS TRACT	EXPOSURE SULFUR DIOXIDE	EXPOSURE PARTICULATES	PROPERTY VALUE TYPE 1	PROPERTY VALUE TYPE 2	GROSS RENT TYPE 3	CONTRACT RENT TYPE 4
355	6	12	523013.	593023.	20350.	0.	78.	63.
356	6	13	250777.	330677.	20286.	45304.	84.	64.
357	6	14	257125.	339049.	19766.	0.	82.	65.
358	6	15	242752.	278228.	20565.	50491.	87.	72.
359	6	16	263378.	356825.	13912.	27267.	60.	46.
360	6	17	56798.	70952.	20710.	0.	89.	69.
361	6	18	342126.	509145.	17237.	0.	69.	52.
362	6	19	146136.	203895.	17641.	0.	74.	55.
363	6	20	421781.	473076.	21098.	0.	78.	58.
17	POLITICAL JURISDICTION TOTALS		4307625.	5159936.	129845216.	166420192.	1140867.	876339.
	POLITICAL JURISDICTION AVERAGES		253390.	303526.	20531.	48617.	81.	62.
	POLITICAL JURISDICTION AIR QUALITY		53.71	64.34	(WEIGHTED WITH RESPECT TO POPULATION)			
364	7	1	113179.	134237.	22945.	62874.	96.	78.
365	7	2	270555.	319118.	22866.	56494.	132.	90.
366	7	3	98520.	116088.	30688.	103063.	157.	108.
3	POLITICAL JURISDICTION TOTALS		482254.	569442.	43564656.	122922832.	140010.	96892.
	POLITICAL JURISDICTION AVERAGES		160751.	189814.	24887.	70221.	132.	91.
	POLITICAL JURISDICTION AIR QUALITY		47.33	55.89	(WEIGHTED WITH RESPECT TO POPULATION)			
273	REGIONAL TOTALS		108290464.	115082576.	5329461248.	9515683840.	18381312.	14288155.
	REGIONAL AVERAGES		396668.	421548.	22365.	66579.	75.	58.
	REGIONAL AIR QUALITY		66.73	70.92	(WEIGHTED WITH RESPECT TO POPULATION)			

Figure E.5-4. Sample Output, Census Tract Property Values Summary from Property Value Module

[illegible]

258

```

FORTTRAN IV G LEVEL 19          PROP          DATE = 71187          19/20/39
0001      SUBROUTINE PROP (LIN1,LIN2,LIN3,LIN4,LOUT1,LOUT2,LOUT3,NCT)
          C
          C *****
          C *
          C * TITLE: PROP
          C *
          C * AUTHOR: B. GOLUSTEIN
          C *
          C * TRW SYSTEMS GROUP
          C * WASHINGTON OPERATIONS
          C *
          C * COMPUTER SYSTEM: TRW SYSTEM 360/MODEL 50
          C *
          C * LANGUAGE USED: FORTTRAN IV - G LEVEL
          C *
          C * ABSTRACT: THIS ROUTINE WILL GENERATE PROPERTY VALUES
          C * BY USING THE ANDERSON-CROCKER REGRESSION
          C * EQUATION.
          C *
          C *****
          C
0002      DIMENSION CONST(4),A(4),B(4),C(4),D(4),E(4),F(4),G(4),H(4),PV(4)
0003      DIMENSION TITLE1(20),TITLE2(20),TITLE3(20),NAME(9),KCT(3)
0004      DIMENSION PJ(6),SR(2),T1(2),T2(3),T3(3),WA(10)
0005      REAL MIL,MPV,MGR,MCR,MFI,NWT,MKM
0006      DATA NAME/'(PV-', '(PSN-', '(PPT-', '(MFI-', '(DLP-', '(OLD-', '(NWT-', '(DIS-',
          1          '(MRM-)'
0007      DATA PJ/' PD-', 'LTI-', 'CAL ', 'JUR-', 'SDIC-', 'TION',
          1          SR/'REGI-', 'ONAL',
          2          T1/' TOT', 'ALS ',
          3          T2/' AVE', 'RAGE', 'S ',
          4          T3/' ATR', 'QUA', 'LITY',
          5          WA/'(WEI', 'GHT', 'D MI', 'TH R', 'ESPE', 'CT T', 'D PD', 'PULA',
          6          'TION', ')'
          C
          C ANDERSON-CROCKER REGRESSION EQUATION:
          C
          C LN(PV) = CONST + A X LN(PSN) + B X LN(PPT) + C X LN(MFI)
          C + D X LN(DLP) + E X LN(OLD) + F X LN(NWT)
          C + G X LN(DIS) + H X LN(MRM)
          C
          C WHERE PV -- PROPERTY VALUE (MEDIAN PROPERTY VALUE, MEDIAN GROSS
          C RENT, OR MEDIAN CONTRACT RENT OF OWNER OCCUPIED
          C HOUSING FOR A CENSUS TRACT)
          C PSN -- CONCENTRATION OF SULFUR DIOXIDE

```

Figure E.5-6. Program Listing for Subprogram PROP,
Property Value Module

FORTRAN IV G LEVEL 19		PROP	DATE = 7/1/87	19/20/39
C		PPT -- CONCENTRATION OF PARTICULATES		
C		MFI -- MEDIAN FAMILY INCOME		
C		DLP -- NUMBER OF LIVING UNITS DILAPIDATED		
C		OLD -- NUMBER OF HOUSES OVER TEN YEARS OLD IN 1959		
C		NWT -- NUMBER OF HOUSING OCCUPIED BY NONWHITES		
C		DTS -- DISTANCE OF CENSUS TRACT FROM CENTRAL BUSINESS DISTRICT		
C		MRM -- MEDIAN NUMBER OF ROOMS IN HOUSING UNIT		
C		CONST -- REGRESSION EQUATION CONSTANT		
C		A,B,C,D,E,F,G,H -- EQUATION COEFFICIENTS		
C		FACTOR -- CONSTANT CORRECTION FACTOR RELATING SULFATION RATE (MILLIGRAMS PER 100 SQUARE CENTIMETER) TO AVERAGE SULFUR DIOXIDE CONCENTRATIONS (PARTS PER MILLION)		
0008	C	READ(LIN1,1100) FACTOR,		
	1	(CONST(I),A(I),B(I),C(I),D(I),E(I),F(I),G(I),H(I),I=1,4)		
0009	C	WRITE(LOUT1,2100) (NAME(1),I,CONST(I),A(I),NAME(2),B(I),NAME(3),		
	1	C(I),NAME(4),D(I),NAME(5),E(I),NAME(6),		
	2	F(I),NAME(7),G(I),NAME(8),H(I),NAME(9),I=1,4)		
0010	C	READ(LIN2,1200) TITLE1		
0011	C	WRITE(LOUT1,2200) TITLE1		
0012	C	ICONT1=0		
0013	C	READ(LIN3,1200) TITLE2		
0014	C	READ(LIN4,1200) TITLE3		
0015	C	WRITE(LOUT2,2300) (TITLE2(I),I=3,18),(TITLE3(I),I=3,18)		
0016	C	ICONT2=0		
0017	C	WRITE(LOUT3,2400) TITLE1,(I,I=1,4)		
0018	C	ICONT3=0		
0019	C	JPJ=1		
0020	C	SCT=0.0		
0021	C	TCT=0.0		
0022	C	SPOP=0.0		
0023	C	TPUP=0.0		

Figure E.5-6. Program Listing for Subprogram PRØP, Property Value Module (Cont'd)

FORTRAN IV G LEVEL 19		PROP	DATE = 71187	19/20/39
0024		SPOSE1=0.0		
0025		SPOSE2=0.0		
0026		TPOSE1=0.0		
0027		TPOSE2=0.0		
	C			
0028		SCT1=0.0		
0029		SCT2=0.0		
0030		TCT1=0.0		
0031		TCT2=0.0		
	C			
0032		SSCT1=0.0		
0033		TTCT1=0.0		
	C			
0034		SPV1=0.0		
0035		SPV2=0.0		
0036		SPV3=0.0		
0037		SPV4=0.0		
0038		TPV1=0.0		
0039		TPV2=0.0		
0040		TPV3=0.0		
0041		TPV4=0.0		
	C			
	C			
0042		DO 110 I=1,NCT		
	C			
0043		READ(LIN2,1300) KCT,Q1,Q2,POP,MIL,SFH,ALL,DWN,RENT,MPV,MGR,MCR, 1 MFI,DLP,CLD,NWT,DIS,MRM		
	C			
0044		IF(ICONT1.LT.48) GO TO 1C		
	C			
0045		WRITE(LJUT1,2200) TITLE1		
	C			
0046		ICONT1=0		
	C			
0047		1C CONTINUE		
	C			
0048		ICONT1=ICONT1+1		
	C			
0049		AMFI=EXP(MFI)		
0050		ADLP=EXP(DLP)		
0051		ADLD=EXP(DLD)		
0052		ANWT=EXP(NWT)		
0053		ADIS=EXP(DIS)		
0054		AMRM=EXP(MRM)		
	C			
0055		WRITE(LJUT1,2500) KCT,POP,MIL,SFH,ALL,MPV,MGR,MCR,AMFI,ADLP,ADLD, 1 ANWT,ADIS,AMRM		
	C			
	C			
0056		READ(LIN3,1400) J1,JPJ1,JCT1,JSCT1,PSN		
	C			
0057		READ(LIN4,1400) J2,JPJ2,JCT2,JSCT2,PPT		

Figure E.5-6. Program Listing for Subprogram PRØP,
Property Value Module (Cont'd)

FJTRAY IV	C	LEVEL	19	PRUP	DATE = 71187	19/20/39
0059	C			IF (ICONT2.LT.49) GO TO 20		
0059	C			WRITE(LOUT2,2300) (TITLE2(IJ),J=3,18),(TITLE3(IJ),J=3,15)		
0060	C			ICONT2=0		
0061	C			20 CONTINUE		
0062	C			ICONT2=ICONT2+1		
0063	C			IF (JSCT1+JSCT2.EQ.0) GO TO 30		
0064	C			WRITE(LOUT2,2610) J1,JPJ1,JCT1,JSCT1,PSN,J2,JPJ2,JCT2,JSCT2,PPT		
0065	C			GO TO 40		
0066	C			30 CONTINUE		
0067	C			WRITE(LOUT2,2620) J1,JPJ1,JCT1,PSN,J2,JPJ2,JCT2,PPT		
0068	C			40 CONTINUE		
0069	C			IF (JPJ1.EQ.JPJ) GO TO 60		
0070	C			IF (ICONT3.LT.49) GO TO 50		
0071	C			WRITE(LOUT3,2400) TITLE1,(J,J=1,4)		
0072	C			ICONT3=0		
0073	C			50 CONTINUE		
0074	C			ICONT3=ICONT3+5		
0075	C			NCT=IFIX(SCT*0.01)		
0076	C			WRITE(LOUT3,2710) NCT,PJ,T1,SPOSE1,SPOSE2,SPV1,SPV2,SPV3,SPV4		
0077	C			APUSE1=SPOSE1/SCT		
0078	C			APUSE2=SPOSE2/SCT		
0079	C			APV1=SPV1/SCT1		
0080	C			APV2=SPV2/SSCT1		
0081	C			APV3=SPV3/SCT2		
0082	C			APV4=SPV4/SCT2		
0083	C			WRITE(LOUT3,2720) PJ,T2,APUSE1,APUSE2,APV1,APV2,APV3,APV4		
0084	C			APUSE1=SPOSE1/SPUP		
0085	C			APUSE2=SPOSE2/SPUP		

Figure E.5-6. Program Listing for Subprogram PRUP,
Property Value Module (Cont'd)

FORTRAN IV G LEVEL 19		PROP	DATE = 71187	19/20/39
0086	C	WRITE(OUTPUT,2730) PJ,I3,APGSE1,APDSE2,WA		
0087	C	JPJ=JPJ1		
0088	C	SCT=0.0		
0089	C	SPOP=0.0		
0090	C	SPOSE1=0.0		
0091	C	SPOSE2=0.0		
0092	C	SCT1=0.0		
0093	C	SCT2=0.0		
0094	C	SSCT1=0.0		
0095	C	SPV1=0.0		
0096	C	SPV2=0.0		
0097	C	SPV3=0.0		
0098	C	SPV4=0.0		
0099	C	60 CONTINUE		
0100	C	IF(Q1.LE.0.0) GO TO 110		
0101	C	POSE1=PSN*POP		
0102	C	POSE2=PPT*POP		
0103	C	PSN=PSN/(2660.0*FACTOR)		
0104	C	PSN=ALOG(PSN)		
0105	C	PPT=ALOG(PPT)		
0106	C	IF(Q1.LT.1.0) GO TO 110		
0107	C	DO 70 J=1,4		
0108	C	PV(J)=EXP(CONST(J)+A(J)*PSN+B(J)*PPT+C(J)*MFI+D(J)*DLP +E(J)*OLD+F(J)*NWT+G(J)*DIS+H(J)*MRM)		
0109	C	70 CONTINUE		
0110	C	IF(Q2.GE.0.75) GO TO 80		
0111	C	PV(2)=0.0		

Figure E.5-6. Program Listing for Subprogram PROP.
Property Value Module (Cont'd)

FORTRAN IV G LEVEL 19		PROP	DATE = 71187	19/20/39
0112		SSCT1=SSCT1-OWN		
0113		TTCT1=TTCT1-OWN		
0114	C	80 CONTINUE		
0115	C	SCT=SCT+1.0		
0116		TCT=TCT+1.0		
0117	C	SPOP=SPOP+POP		
0118		TPOP=TPOP+POP		
0119	C	SPOSE1=SPOSE1+POSE1		
0120		SPOSE2=SPOSE2+POSE2		
0121		TPUSE1=TPUSE1+POSE1		
0122		TPUSE2=TPUSE2+POSE2		
0123	C	SCT1=SCT1+OWN		
0124		SCT2=SCT2+RENT		
0125		TCT1=TCT1+OWN		
0126		TCT2=TCT2+RENT		
0127	C	SSCT1=SSCT1+OWN		
0128		TTCT1=TTCT1+OWN		
0129	C	PV1=PV(1)*OWN		
0130		PV2=PV(2)*OWN		
0131		PV3=PV(3)*RENT		
0132		PV4=PV(4)*RENT		
0133	C	SPV1=SPV1+PV1		
0134		SPV2=SPV2+PV2		
0135		SPV3=SPV3+PV3		
0136		SPV4=SPV4+PV4		
0137		TPV1=TPV1+PV1		
0138		TPV2=TPV2+PV2		
0139		TPV3=TPV3+PV3		
0140		TPV4=TPV4+PV4		
0141	C	IF(ICON3.LT.4) GO TO 90		
0142	C	WRITE(LOUT3,2400) TITL1,(J,J=1,4)		
0143	C	ICON3=0		
0144	C	90 CONTINUE		
0145	C	ICON3=ICON3+1		
0146	C	IF(JSCT1.EQ.CT GO TO 100		
0147	C	WRITE(LOUT3,2410) I,JPJ1,JCT1,JSCT1,POSE1,POSE2,(PV1J),J=1,4)		

Figure E.5-6. Program Listing for Subprogram PRØP, Property Value Module (Cont'd)

FORTRAN IV G LEVEL 19		PROP	DATE = 71107	19/20/39
0148	C	GO TO 110		
0149	C	100 CONTINUE		
0150	C	WRITE(LOUT3,2420) T,JPJ1,JCT1,POSE1,POSE2,(PV(J),J=1,4)		
0151	C	110 CONTINUE		
0152	C	IF(ICONT3.LT.45) GO TO 120		
0153	C	WRITE(LOUT3,2400) TITLE1,(J,J=1,4)		
0154	C	ICONT3=0		
0155	C	120 CONTINUE		
0156	C	ICONT3=ICONT3+5		
0157	C	MCT=IFIX(SCT*0.01)		
0158	C	WRITE(LOUT3,2710) MCT,PJ,T1,SPOSE1,SPOSE2,SPV1,SPV2,SPV3,SPV4		
0159	C	APOSE1=SPOSE1/SCT		
0160	C	APOSE2=SPOSE2/SCT		
0161	C	APV1=SPV1/SCT1		
0162	C	APV2=SPV2/SSCT1		
0163	C	APV3=SPV3/SCT2		
0164	C	APV4=SPV4/SCT2		
0165	C	WRITE(LOUT3,2720) PJ,T2,APOSE1,APOSE2,APV1,APV2,APV3,APV4		
0166	C	APOSE1=SPOSE1/SPOP		
0167	C	APOSE2=SPOSE2/SPOP		
0168	C	WRITE(LOUT3,2730) PJ,T3,APCSE1,APOSE2,WA		
0169	C	IF(ICONT3.GT.44) WRITE(LOUT3,2400) TITLE1,(J,J=1,4)		
0170	C	MCT=IFIX(TCT*0.01)		
0171	C	WRITE(LOUT3,2910) MCT,SR,T1,TPOSE1,TPOSE2,TPV1,TPV2,TPV3,TPV4		
0172	C	APOSE1=TPOSE1/TCT		
0173	C	APOSE2=TPOSE2/TCT		
0174	C	APV1=TPV1/TCT1		
0175	C	APV2=TPV2/TCT1		
0176	C	APV3=TPV3/TCT2		

Figure E.5-6. Program Listing for Subprogram PRØP, Property Value Module (Cont'd)

FORTRAN IV G LEVEL 19		PROP	DATE = 71187	19/20/39
0177		APV4=TPV4/TCT2		
0178	C	WRITE(LOUT3,2920) SR,T2,APCSE1,APCSE2,APV1,APV2,APV3,APV4		
0179	C	APCSE1=TPOSE1/TPCP		
0180	C	APCSE2=TPOSE2/TPCP		
0181	C	WRITE(LOUT3,2930) SR,T3,APCSE1,APCSE2,AA		
0182	C	RETURN		
0183	C	1100 FORMAT(F5.3/(F8.4,8X))		
0184	C	1200 FORMAT(20A4)		
0185	C	1300 FORMAT(2A4,A1,1X,F6.2,F6.3,6F8.2/10X,F6.2,2F7.2,5F8.3,F8.4)		
0186	C	1400 FORMAT(3I5,11,4X,F10.3)		
0187	C	2100 FORMAT('1',48X,'ANDERSON-CROCKER REGRESSION EQUATION'///		
	1	4('////////13X,'LN',A4,11,'') = ('F7.4,'),		
	2	4(' + ('F7.4,' x LN',A4,'))'//33X,		
	3	4(' + ('F7.4,' x LN',A4,'))'//33X,		
0188	C	2200 FORMAT('1',49X,'CENSUS TRACT ATTRIBUTES -- INPUT'//1X,20A4//		
	1	4X,'CENSUS',4X,'TOTAL',5X,'AREA IN',2X,'SINGLE',5X,'ALL',		
	2	5X,'MEDIAN',2X,'MEDIAN',2X,'MEDIAN',3X,'MEDIAN',		
	3	1X,'DILAPIDATED',2X,'HOUSING',2X,'NONWHITE',1X,'DISTANCE',		
	4	2X,'MEDIAN',4X,'TRACT',3X,'POPULATION',3X,'SQUARE',		
	5	2X,'FAMILY',3X,'HOUSING',2X,'PROPERTY',2X,'GROSS',		
	6	1X,'CONTRACT',2X,'FAMILY',3X,'HOUSING',4X,'OVER 10',		
	7	2X,'OCCUPIED',1X,'BUSINESS',1X,'ROOMS IN',4X,'NUMBER',		
	8	15X,'MILES',3X,'HOUSING',3X,'UNITS',4X,'VALUE',4X,'RENT',		
	9	4X,'RENT',4X,'INCOME',4X,'UNITS',4X,'YEARS OLD',		
	A	1X,'HOUSING',2X,'DISTRICT',2X,'HOUSING'//		
0189	C	2300 FORMAT('1',42X,'CENSUS TRACT POLLUTANT CONCENTRATIONS -- INPUT'//1X,16A4,4X,16A4//		
	2	3X,'NUMBER',4X,'POLITICAL',5X,'CENSUS',		
	3	5X,'POLLUTANT CONCENTRATION',		
	4	9X,'NUMBER',4X,'POLITICAL',5X,'CENSUS',		
	5	5X,'POLLUTANT CONCENTRATION'//		
	6	12X,'JURISDICTION',3X,'TRACT',		
	7	4X,'(MICROGRAMS PER CUBIC METER)',		
	8	15X,'JURISDICTION',3X,'TRACT',		
	9	4X,'(MICROGRAMS PER CUBIC METER)'//		
0190	C	2400 FORMAT('1',53X,'CENSUS TRACT PROPERTY VALUE'//1X,20A4//		
	1	2X,'NUMBER',6X,'POLITICAL',7X,'CENSUS',12X,'EXPOSURE',		

Figure E.5-6. Program Listing for Subprogram PRØP, Property Value Module (Cont'd)

FORTRAN IV G LEVEL 19		PROP	DATE = 71187	19/20/39
	2	9X, 'EXPOSURE', 12X, 'PROPERTY', 5X, 'PROPERTY', 6X, 'GROSS',		
	3	7X, 'CONTRACT', 13X, 'JURISDICTION', 5X, 'TRACT', 14X, 'SULFUR',		
	4	8X, 'PARTICULATES', 11X, 'VALUE', 8X, 'VALUE', 9X, 'RENT',		
	5	9X, 'RENT', 48X, 'DIOXIDE', 24X, 4(7X, 'TYPE', 12)/)		
	C			
0191	2500	FORMAT(1X, 2A4, A1, F10.0, F10.0, F10.0, F9.0, F10.0, F7.0, F8.0, F9.0, F9.0,		
	1	F11.0, F10.0, F8.1, F9.1)		
	C			
0192	2610	FORMAT(1X, 16, I12, I12, '.', I1, F19.2, I22, I12, I12, '.', I1, F19.2)		
	C			
0193	2620	FORMAT(1X, 16, I12, I12, F21.2, I22, I12, I12, F21.2)		
	C			
0194	2710	FORMAT('0', 15, 4X, 6A4, 2A4, F14.0, F17.0, F19.0, F13.0, F12.0, F13.0)		
	C			
0195	2720	FORMAT(10X, 6A4, 3A4, F10.0, F17.0, F19.0, F13.0, F12.0, F13.0)		
	C			
0196	2730	FORMAT(10X, 6A4, 3A4, F12.2, F17.2, 11X, 10A4/)		
	C			
0197	2810	FORMAT(1X, 15, I14, I14, '.', I1, F20.0, F17.0, F19.0, F13.0, F12.0, F13.0)		
	C			
0198	2820	FORMAT(1X, 15, I14, I14, F22.0, F17.0, F19.0, F13.0, F12.0, F13.0)		
	C			
0199	2910	FORMAT('0', 15, 6X, 2A4, 2A4, F28.0, F17.0, F19.0, F13.0, F12.0, F13.0)		
	C			
0200	2920	FORMAT(12X, 2A4, 3A4, F24.0, F17.0, F19.0, F13.0, F12.0, F13.0)		
	C			
0201	2930	FORMAT(12X, 2A4, 3A4, F26.2, F17.2, 11X, 10A4)		
	C			
	C			
0202		END		

Figure E.5-6. Program Listing for Subprogram PROP, Property Value Module (Cont'd)

6.0 ASSIGNMENT MODULE

6.1 DESCRIPTION

The Assignment Module (ASSIGN) determines census tract residential property values under different conditions of ambient air quality. The algorithm is described in Chapter 2, Section 2.6.

6.2 JOB CONTROL LANGUAGE AND DECK SET-UP

Figure E.6-1 shows the JCL and deck set-up for the Assignment Module. The ordering parallels that of PRØP identically.

6.3 DIMENSION AND INPUT DATA FORMATS

All variable dimension information and data set descriptions are the same as given in Section 5.3 of this appendix. However, Data Set 13 is now:

LØUT3/13/-Output data set, i.e., printer-census tract
property value bids.

The input data formats for Data Set 1 (LIN1) are shown in Table E.6-1. Everything follows the formats for the sulfation rate factor and regression coefficient input cards described for PRØP. However, only one regression coefficient set (one input card), corresponding to the Type I property value equation, is required for ASSIGN.

Table E.6-2 shows the data formats for Data Set 2 (LIN2), which corresponds to the census tract attribute deck produced by CØNVRT. However, ASSIGN reads fewer attributes into core than PRØP. The attributes skipped are indicated by the notation "(SKIP)".

The input data formats corresponding to Data Set 3 (LIN3) and Data Set 4 (LIN4) are the same as given for PRØP.

JOB SETUP FOR ASSIGN MODEL

```
//ASSIGN EXEC PROC=FORTGCLG
//FORT.SYSIN DD *
```

SOURCE DECKS

```
/*
//LKED.SYSIN DD *
```

OBJECT DECKS

```
/*
//GO.FT11F001 DD SYSOUT=A,DCB=(RECFM=UA,LRECL=133,BLKSIZE=133)
//GO.FT12F001 DD SYSOUT=A,DCB=(RECFM=UA,LRECL=133,BLKSIZE=133)
//GO.FT13F001 DD SYSOUT=A,DCB=(RECFM=UA,LRECL=133,BLKSIZE=133)
//GO.FT01F001 DD *
```

REGRESSION LINE COEFFICIENTS

```
/*
//GO.FT02F001 DD *
```

CENSUS TRACT ATTRIBUTE DATA DECK

```
/*
//GO.FT03F001 DD *
```

AIR QUALITY DATA DECK - SO2

```
/*
//GO.FT04F001 DD *
```

AIR QUALITY DATA DECK - PARTICULATES

```
/*
```

Figure E.6-1. Job Control Language and Deck Set-Up for Assignment Module

Table E.6-1. Assignment Module Input Format for
Regression Coefficients (Type I)

	<u>Parameter</u>	<u>Columns</u>	<u>Format</u>
<u>CARD 1</u>			
	FACTØR	1-5	F5.3
<u>CARD 2</u>			
	CØNST	1-8	F8.4
	A	9-16	F8.4
	B	17-24	F8.4
	C	25-32	F8.4
	D	33-40	F8.4
	E	41-48	F8.4
	F	49-56	F8.4
	G	57-64	F8.4
	H	65-72	F8.4

Table E.6-2.

Census Tract Attribute Data Formats as Read by Assignment Module

	<u>Parameter</u>	<u>Columns</u>	<u>Format</u>
NCT Census Tract, two cards per census tract.	<u>CARD 1</u>		
	TITLE1	1-80	20A4
	- left justified title information beginning in column three.		
	<u>CARD 2</u>		
	KCT	1-9	2A4,A1
	(BLANK)	10	1X
	Q1	11-16	F6.2
	(SKIP)	17-22	6X
	PØP	23-30	F8.2
	MIL	31-38	F8.2
	<u>CARD 3</u>		
	(SKIP)	1-10	10X
	MPV	11-18	F8.2
	(SKIP)	19-32	14X
	Ln(MFI)	33-40	F8.3
	Ln(DLP)	41-48	F8.3
	Ln(OLD)	49-56	F8.3
	Ln(NWT)	57-64	F8.3
	Ln(DIS)	65-72	F8.3
	Ln(MRM)	73-80	F8.4

6.4 OUTPUT AND PROGRAM LISTINGS

Figures E.6-2 and E.6-3 show the input data summaries corresponding to Data Set 11 (LØUT1) and Data Set 12 (LØUT2) as described in Section 5.4. The major output from ASSIGN is shown in Figure E.6-4, corresponding to Data Set 13 (LØUT3). The sample outputs are for the NCIAQCR demonstration using EXISTING SO₂ and EXISTING PARTICULATE air quality data.

Program listings for the DRIVER program of the Assignment Module and the ASSIGN subprogram are given in Figures E.6-5 and E.6-6.

ANDERSON-CROCKER REGRESSION EQUATION

$$\begin{aligned} \text{LN(PV)} = & (3.3901) + (-0.0712 \times \text{LN(PSN)}) + (-0.0610 \times \text{LN(PPT)}) + (0.7677 \times \text{LN(MFI)}) + (0.0044 \times \text{LN(DLP)}) \\ & + (-0.0106 \times \text{LN(OLD)}) + (0.0251 \times \text{LN(NMT)}) + (-0.0582 \times \text{LN(DIS)}) + (0.0 \times \text{LN(MRM)}) \end{aligned}$$

CENSUS TRACT ATTRIBUTES -- INPUT

WASHINGTON, D.C.

CENSUS TRACT NUMBER	TOTAL POPULATION	AREA IN SQUARE MILES	MEDIAN PROPERTY VALUE	MEDIAN FAMILY INCOME	DILAPIDATED HOUSING UNITS	HOUSING OVER 10 YEARS OLD	NONWHITE OCCUPIED HOUSING	DISTANCE BUSINESS DISTRICT	MEDIAN ROOMS IN HOUSING
0048	8485.	186.	12100.	3200.	340.	2292.	2213.	1.5	3.7
0049	9000.	115.	12296.	3474.	102.	2925.	2657.	1.5	2.6
0050	8234.	115.	14003.	3467.	26.	3855.	2485.	2.0	2.3
0051	2451.	0.	0.	1.	1.	1.	1.	1.0	1.0
0052001	6033.	115.	13200.	4163.	1.	3100.	1232.		
0052002	1291.	0.	0.	1.	1.	1.			
0053001	5896.	58.	11696.	5187.	23.	3429.			
0053002	1022.	0.	0.	1.	1.				
0054001	2624.	0.	0.	1.	1.				
0054002	831.	0.	0.	1.	1.				
0055	6180.	237.	19594.	4803.	1.				
0056	3797.	160.	21590.	7856.					
0057001	5378.	173.	22994.						
0057002	1404.	0.							
0058	1489.	0.							
0059	5820.	0.							

Figure E.6-2. Sample Output, Title Page and Census Tract Attributes-Assignment Module.

CENSUS TRACT POLLUTANT CONCENTRATIONS -- INPUT

WASHINGTON, D.C., EXISTING -- SULFUR DIOXIDE				WASHINGTON, D.C., EXISTING -- PARTICULATES			
NUMBER	POLITICAL JURISDICTION	CENSUS TRACT	POLLUTANT CONCENTRATION (MICROGRAMS PER CUBIC METER)	NUMBER	POLITICAL JURISDICTION	CENSUS TRACT	POLLUTANT CONCENTRATION (MICROGRAMS PER CUBIC METER)
1	1	1	64.78	1	1	1	77.29
2	1	2	61.08	2	1	2	64.63
3	1	3	61.08	3	1	3	64.63
4	1	4	63.34	4	1	4	66.70
5	1	5	65.39	5	1	5	67.89
6	1	6	56.88	6	1	6	63.56
7	1	7	58.98	7	1	7	64.09
8	1	8	56.65	8	1	8	62.32
9	1	9	54.08	9	1	9	61.42
10	1	10	56.88	10	1	10	63.56
11	1	11	51.77	11	1	11	63.01
12	1	12	56.88	12	1	12	63.56
13	1	13	61.40	13	1	13	67.06
14	1	14	58.58	14	1	14	66.60
15	1	15	55.22	15	1	15	65.21
16	1	16	63.78	16	1	16	67.97
17	1	17	71.15	17	1	17	72.79
18	1	18	70.50	18	1	18	70.75
19	1	19	74.51	19	1	19	74.18
20	1	20	71.02	20	1	20	71.10
21	1	21	78.91	21	1	21	76.13
22	1	22	78.91	22	1	22	76.13
23	1	23.1	83.31	23	1	23.1	78.08
24	1	23.2	89.34	24	1	23.2	81.03
25	1	24	83.31	25	1	24	78.08
26	1	25	71.55	26	1	25	71.46
27	1	26	71.55	27	1	26	71.46
28	1	27	71.80	28	1	27	71.69
29	1	28	71.80	29	1	28	71.69
30	1	29	71.80	30	1	29	71.69
31	1	30	71.80	31	1	30	71.69
32	1	31	79.56	32	1	31	76.03
33	1	32	79.56	33	1	32	76.03
34	1	33	86.73	34	1	33	79.41
35	1	34	83.56	35	1	34	78.31
36	1	35	81.67	36	1	35	76.76
37	1	36	72.06	37	1	36	71.92
38	1	37	71.80	38	1	37	71.69
39	1	38	71.80	39	1	38	71.69
40	1	39	68.23	40	1	39	69.34
41	1	40	68.23	41	1	40	69.34
42	1	41	66.57	42	1	41	68.27
43	1	42	72.06	43	1	42	71.92
44	1	43	72.06	44	1	43	71.92
45	1	44	72.06	45	1	44	71.92
46	1	45	72.06	46	1	45	71.92
47	1	46	86.73	47	1	46	79.41
48	1	47	83.00	48	1	47	77.63
49	1	48	86.73	49	1	48	79.41

Figure E.6-3. Sample Output, Census Tract Pollutant Concentration Summary (SO₂ and Particulates) Assignment Module.

WASHINGTON, D.C.							
CENSUS TRACT PROPERTY VALUE BIDS							
NUMBER	POLITICAL JURISDICTION	CENSUS TRACT	MEDIAN PROPERTY VALUE	PROPERTY VALUE BEFORE SHIFT	PROPERTY VALUE AFTER SHIFT	DIFFERENCE IN PROPERTY VALUE	
257	6	6	15899.	20971.	19081.	-1890.	
258	6	7	11396.	17119.	22830.	5711.	
259	6	8	22093.	20628.	22138.	1510.	
260	6	9	23295.	28263.	19839.	-8424.	
261	6	11	23295.	22067.	22220.	153.	
262	6	12	12900.	20350.	21590.	1239.	
263	6	13	12695.	20286.	20983.	697.	
264	6	14	14300.	19766.	18588.	-1177.	
265	6	15	16301.	20565.	11519.	-9046.	
266	6	16	11204.	13912.	28321.	14410.	
267	6	17	23295.	20710.	19808.	-902.	
268	6	18	13494.	17237.	24651.	7414.	
269	6	19	14003.	17641.	24353.	6712.	
270	6	20	16899.	21098.	24713.	3615.	
17	POLITICAL JURISDICTION TOTALS		101821712.	129845216.	138932352.	9087147.	
	POLITICAL JURISDICTION AVERAGES		16100.	20531.	21968.	1437.	
271	7	1	18306.	22945.	14677.	-8268.	
272	7	2	18106.	22866.	23507.	641.	
273	7	3	26108.	30686.	23747.	-6941.	
3	POLITICAL JURISDICTION TOTALS		35373824.	43564656.	36821904.	-6742747.	
	POLITICAL JURISDICTION AVERAGES		20208.	24887.	21035.	-3852.	
273	REGIONAL TOTALS		4171612416.	5329461248.	4879036416.	-450462720.	
	REGIONAL AVERAGES		17506.	22365.	20475.	-1890.	

Figure E.6-4. Sample Output, Census Tract Property Value Bids from Assignment Module.

FORTRAN IV G LEVEL 19		MAIN	DATE = 71144	20/10/28
	C	DRIVER FOR ASSIGNMENT ROUTINE		
	C			
	C			
0001	C	DIMENSION IDCT(366),PV(4,366),HH(366),CT(366),IT(366)		*
	C			
0002	C	DATA LIN1/1/,LIN2/2/,LIN3/3/,LIN4/4/,		*
	1	LOUT1/11/,LOUT2/12/,LOUT3/13/,		*
	2	NCT/366/		*
	C			
	C			
0003	C	CALL ASSIGN (LIN1,LIN2,LIN3,LIN4,LOUT1,LOUT2,LOUT3,		
	1	NCT,IDCT,PV,HH,CT,IT)		
	C			
	C			
0004	C	STOP		
	C			
	C			
0005	C	END		

Figure E.6-5. Program Listing for DRIVER, Main Program for Assignment Module.


```

FORTRAN IV G LEVEL 19          ASSIGN          DATE = 71189          08/10/21
0001      SUBROUTINE ASSIGN (LIN1,LIN2,LIN3,LIN4,LOUT1,LOUT2,LOUT3,
          1      NCT,IDCT,PV,HH,CT,IT,OWN1,OWN2)
          C
          C *****
          C *
          C * TITLE: ASSIGN
          C *
          C * AUTHOR: B. GOLDSTEIN
          C *
          C * TRW SYSTEMS GROUP
          C * WASHINGTON OPERATIONS
          C *
          C * COMPUTER SYSTEM: IBM SYSTEM 360/MODEL 50
          C *
          C * LANGUAGE USED: FORTRAN IV - G LEVEL
          C *
          C * ABSTRACT: TO APPROXIMATE, AS CLOSELY AS POSSIBLE, THE NET
          C * INCREASE IN PRODUCTIVITY OCCASIONED BY REDUCTIONS
          C * IN AMBIENT AIR CONCENTRATIONS OF SULFUR OXIDES
          C * AND PARTICULATES.
          C *
          C *****
          C
0002      DIMENSION IDCT(NCT),PV(4,NCT),HH(NCT),CT(NCT),IT(NCT),
          1      OWN1(NCT),OWN2(NCT)
0003      DIMENSION TITLE1(20),TITLE2(20),TITLE3(20),KCT(3)
0004      DIMENSION PJ(6),SR(2),T1(2),T2(3)
0005      REAL MIL,MPV,MFI,NWT,MHM
0006      DATA PJ/' PO','LITI','CAL ','JURI','SDIC','TION'/,
          1      SR/'REGI','ONAL'/,
          2      T1/' TOT','ALS '/,
          3      T2/' AVE','RAGE','S '/
          C
          C
          C ANDERSON-CROCKER REGRESSION EQUATION:
          C
          C LN(PV) = CONST + A X LN(PSN) + B X LN(PPT) + C X LN(MFI)
          C + D X LN(DLP) + E X LN(OLD) + F X LN(NWT)
          C + G X LN(DIS) + H X LN(MRM)
          C
          C WHERE PV -- PROPERTY VALUE OF OWNER OCCUPIED HOUSING
          C PSN -- CONCENTRATION OF SULFUR DIOXIDE
          C PPT -- CONCENTRATION OF PARTICULATES
          C MFI -- MEDIAN FAMILY INCOME
          C DLP -- NUMBER OF LIVING UNITS DILAPIDATED
          C OLD -- NUMBER OF HOUSES OVER TEN YEARS OLD IN 1959
          C NWT -- NUMBER OF HOUSING OCCUPIED BY NONWHITES

```

Figure E.6-6. Program Listing for ASSIGN
Subprogram, Assignment Module.

FORTRAN IV G LEVEL 19		ASSIGN	DATE = 71109	08/10/21
	C	DIS -- DISTANCE OF CENSUS TRACT FROM CENTRAL BUSINESS		
	C	DISTRICT		
	C	MRM -- MEDIAN NUMBER OF ROOMS IN HOUSING UNIT		
	C	CONST -- REGRESSION EQUATION CONSTANT		
	C	A,B,C,D,E,F,G,H -- EQUATION COEFFICIENTS		
	C	FACTOR -- CONSTANT CORRECTION FACTOR RELATING SULFATION		
	C	RATE (MILLIGRAMS PER 100 SQUARE CENTIMETER) TO		
	C	AVERAGE SULFUR DIOXIDE CONCENTRATIONS (PARTS PER		
	C	MILLION)		
0007	C	READ(LIN1,1100) FACTOR,CONST,A,B,C,D,E,F,G,H		
0008	C	WRITE(LOUT1,2100) CONST,A,B,C,D,E,F,G,H		
0009	C	READ(LIN2,1200) TITLE1		
0010	C	WRITE(LOUT1,2200) TITLE1		
0011	C	ICONT1=0		
0012	C	READ(LIN3,1200) TITLE2		
0013	C	READ(LIN4,1200) TITLE3		
0014	C	WRITE(LOUT2,2300) (TITLE2(1),I=3,18),(TITLE3(1),I=3,18)		
0015	C	ICONT2=0		
0016	C	WRITE(LOUT3,2400) TITLE1		
0017	C	ICONT3=0		
0018	C	N=0		
0019	C	DO 50 I=1,NCT		
0020	C	READ(LIN2,1300) KCT,Q1,POP,MIL,CWN,MPV,MFI,DLP,OLD,NWT,DIS,MRM		
0021		AMFI=EXP(MFI)		
0022		ADLP=EXP(DLP)		
0023		AOLD=EXP(OLD)		
0024		ANWT=EXP(NWT)		
0025		ADIS=EXP(DIS)		
0026		AMRM=EXP(MRM)		
0027	C	IF(ICONT1.LT.48) GO TO 10		
0028	C	WRITE(LOUT1,2200) TITLE1		

Figure E.6-6. Program Listing for ASSIGN Subprogram,
Assignment Module (Cont'd)

FORTRAN IV G LEVEL 19		ASSIGN	DATE = 71189	08/10/21
0029	C	ICONT1=0		
0030	C	10 CONTINUE		
0031	C	ICONT1=ICONT1+1		
0032	C	WRITE(LOUT1,2500) KCT,POP,MIL,MPV,AMFI,ADLP,AOLD,ANWT,ADIS,ANRM		
0033	C	READ(LIN3,1400) J1,JPJ1,JCT1,JSCT1,PSN		
0034	C	READ(LIN4,1400) J2,JPJ2,JCT2,JSCT2,PPT		
0035	C	IF(ICONT2.LT.49) GO TO 20		
0036	C	WRITE(LOUT2,2300) (TITLE2(J),J=3,18),(TITLE3(J),J=3,18)		
0037	C	ICONT2=0		
0038	C	20 CONTINUE		
0039	C	ICONT2=ICONT2+1		
0040	C	IF(JSCT1+JSCT2.EQ.0) GO TO 30		
0041	C	WRITE(LOUT2,2610) J1,JPJ1,JCT1,JSCT1,PSN,J2,JPJ2,JCT2,JSCT2,PPT		
0042	C	GO TO 40		
0043	C	30 CONTINUE		
0044	C	WRITE(LOUT2,2620) J1,JPJ1,JCT1,PSN,J2,JPJ2,JCT2,PPT		
0045	C	40 CONTINUE		
0046	C	IF(Q1.LT.1.0) GO TO 50		
0047	C	N=N+1		
0048	C	IDCT(N)=JPJ1*10000+JCT1*10+JSCT1		
0049	C	PV(1,N)=MPV		
0050	C	PSN=PSN/(2660.0*FACTOR)		
0051	C	PSN=ALOG(PSN)		
0052	C	PPT=ALOG(PPT)		

Figure E.6-6. Program Listing for ASSIGN Subprogram, Assignment Module (Cont'd)

FORTRAN IV G LEVEL 19		ASSIGN	DATE = 71189	08/10/21
0053	C	HH(N)=C*MF1		
0054	C	CT(N)=CONST*A*PSN+B*PPT+D*DLP+E*OLD+F*NEW+G*DIS+H*MM		
0055	C	IT(N)=N		
0056	C	OWN1(N)=OWN		
0057	C	PV(2,N)=EXP(HH(N)+CT(N))		
0058	C	50 CONTINUE		
0059	C	NN=N-1		
0060	C	DO 80 J=1,NN		
0061	C	II=N-J		
0062	C	III=II+1		
0063	C	DO 70 I=1,II		
0064	C	IF(HH(I).GE.HH(III)) GO TO 60		
0065	C	TEMP=HH(III)		
0066	C	HH(III)=HH(I)		
0067	C	HH(I)=TEMP		
0068	C	60 CONTINUE		
0069	C	IF(CT(I).GE.CT(III)) GO TO 70		
0070	C	TEMP=CT(III)		
0071	C	CT(III)=CT(I)		
0072	C	CT(I)=TEMP		
0073	C	ITEMP=IT(III)		
0074	C	IT(III)=IT(I)		
0075	C	IT(I)=ITEMP		
0076	C	TEMP=OWN1(III)		
0077	C	OWN1(III)=OWN1(I)		
0078	C	OWN1(I)=TEMP		
0079	C	70 CONTINUE		
0080	C	80 CONTINUE		
0081	C	DO 90 I=1,N		
0082	C	II=IT(I)		

Figure E.6-6. Program Listing for ASSIGN Subprogram, Assignment Module (Cont'd)

FORTRAN IV G LEVEL 19		ASSIGN	DATE = 71189	08/10/21
0083	C	PV(3,11)=EXP(HH(1)+CT(1))		
0084	C	OWN2(11)=OWN1(1)		
0085	C	90 CONTINUE		
0086	C	JPJ=1		
0087	C	MSCT=0		
0088	C	MTCT=0		
0089	C	SCT=0.0		
0090	C	TCT=0.0		
0091	C	SPV1=0.0		
0092	C	SPV2=0.0		
0093	C	SPV3=0.0		
0094	C	SPV4=0.0		
0095	C	TPV1=0.0		
0096	C	TPV2=0.0		
0097	C	TPV3=0.0		
0098	C	TPV4=0.0		
0099	C	DO 140 I=1,N		
0100	C	ID=IDCT(1)		
0101	C	IPJ=ID/10000		
0102	C	ID=ID-IPJ*10000		
0103	C	ICT=ID/10		
0104	C	ISCT=ID-ICT*10		
0105	C	OWN=OWN2(1)		
0106	C	IF(IPJ.EQ.JPJ) GO TO 110		
0107	C	IF(ICONT3.LT.44) GO TO 100		
0108	C	WRITE(LOUT3,2400) TITLE1		
0109	C	ICONT3=0		
0110	C	100 CONTINUE		
0111	C	ICONT3=ICONT3+4		

Figure E.6-6. Program Listing for ASSIGN Subprogram, Assignment Module (Cont'd)

FORTRAN IV G LEVEL 19		ASSIGN	DATE = 71189	08/10/21
0112	C	WRITE(LOUT3,2710) MSCT,PJ,T1,SPV1,SPV2,SPV3,SPV4		
0113	C	APV1=SPV1/SCT		
0114		APV2=SPV2/SCT		
0115		APV3=SPV3/SCT		
0116		APV4=SPV4/SCT		
0117	C	WRITE(LOUT3,2720) PJ,T2,APV1,APV2,APV3,APV4		
0118	C	JPJ=IPJ		
0119	C	MSCT=0		
0120	C	SCT=0.0		
0121	C	SPV1=0.0		
0122		SPV2=0.0		
0123		SPV3=0.0		
0124		SPV4=0.0		
0125	C	110 CONTINUE		
0126	C	PV(4,I)=PV(3,I)-PV(2,I)		
0127	C	MSCT=MSCT+1		
0128	C	MTCT=MTCT+1		
0129	C	SCT=SCT+OWN		
0130		TCT=TCT+OWN		
0131	C	PV1=PV(1,I)*OWN		
0132		PV2=PV(2,I)*OWN		
0133		PV3=PV(3,I)*OWN		
0134		PV4=PV(4,I)*OWN		
0135	C	SPV1=SPV1+PV1		
0136		SPV2=SPV2+PV2		
0137		SPV3=SPV3+PV3		
0138		SPV4=SPV4+PV4		
0139		TPV1=TPV1+PV1		
0140		TPV2=TPV2+PV2		
0141		TPV3=TPV3+PV3		
0142		TPV4=TPV4+PV4		
0143	C	IF(ICONT3.LT.46) GO TO 120		
0144	C	WRITE(LOUT3,2400) TITLE1		

Figure E.6-6. Program Listing for ASSIGN Subprogram, Assignment Module (Cont'd)

ORTRAN IV G LEVEL 19		ASSIGN	DATE = 71189	C8/10/21
0145		ICONT3=0		
0146	C	120 CONTINUE		
0147	C	ICONT3=ICONT3+1		
0148	C	IF (ISCT.EQ.0) GO TO 130		
0149	C	WRITE(LOUT3,2810) I,IPJ,ICT,ISCT,(PV(J,I),J=1,4)		
0150	C	GO TO 140		
0151	C	130 CONTINUE		
0152	C	WRITE(LOUT3,2820) I,IPJ,ICT,(PV(J,I),J=1,4)		
0153	C	140 CONTINUE		
0154	C	IF (ICONT3.LT.44) GO TO 150		
0155	C	WRITE(LOUT3,2400) TITLE1		
0156	C	ICONT3=0		
0157	C	150 CONTINUE		
0158	C	ICONT3=ICONT3+4		
0159	C	WRITE(LOUT3,2710) HSCY,PJ,Y1,SPV1,SPV2,SPV3,SPV4		
0160		APV1=SPV1/SCT		
0161		APV2=SPV2/SCT		
0162		APV3=SPV3/SCT		
0163		APV4=SPV4/SCT		
0164	C	WRITE(LOUT3,2720) PJ,T2,APV1,APV2,APV3,APV4		
0165	C	IF (ICONT3.GT.43) WRITE(LOUT3,2400) TITLE1		
0166	C	WRITE(LOUT3,2910) HSCY,SR,Y1,TPV1,TPV2,TPV3,TPV4		
0167		APV1=TPV1/TCT		
0168		APV2=TPV2/TCT		
0169		APV3=TPV3/TCT		
0170		APV4=TPV4/TCT		
0171	C	WRITE(LOUT3,2920) SR,T2,APV1,APV2,APV3,APV4		
0172	C	RETURN		

Figure E.6-6. Program Listing for ASSIGN Subprogram, Assignment Module (Cont'd)

FORTRAN IV G LEVEL 19		ASSIGN	DATE = 71189	09/10/21
	C			
0173	C	1100 FORMAT(F5.3/9F8.4)		
	C			
0174	C	1200 FORMAT(20A4)		
	C			
0175	C	1300 FORMAT(2A4,A1,1X,F6.2,6X,2F8.2,16X,F8.2/10X,F8.2,14X,5F8.3,F8.4)		
	C			
0176	C	1400 FORMAT(3I5,11,4X,F10.3)		
	C			
0177	C	2100 FORMAT('1',48X,'ANDERSON-CROCKER REGRESSION EQUATION'///////// 1 14X,'LN(PV) = ('F7.4,') + ('F7.4,' X LN(PSN)) + ('F7.4, 2 ' X LN(PPT)) + ('F7.4,' X LN(MFI)) + ('F7.4, 3 ' X LN(DLP))//33X,'+ ('F7.4,' X LN(OLD)) + ('F7.4, 4 ' X LN(NMT)) + ('F7.4,' X LN(DIS)) + ('F7.4, 5 ' X LN(MRM))')		
	C			
0178	C	2200 FORMAT('1',49X,'CENSUS TRACT ATTRIBUTES -- INPUT'//1X,20A4// 1 8X,'CENSUS',7X,'TOTAL',8X,'AREA IN',6X,'MEDIAN', 2 6X,'MEDIAN',4X,'DILAPIDATED',5X,'HOUSING',5X,'NONWHITE', 3 4X,'DISTANCE',5X,'MEDIAN'/8X,'TRACT',6X,'POPULATION', 4 6X,'SQUARE',5X,'PROPERTY',5X,'FAMILY',6X,'HOUSING', 5 7X,'OVER 10',5X,'OCCUPIED',4X,'BUSINESS',4X,'ROOMS IN', 6 8X,'NUMBER',21X,'MILES',7X,'VALUE',7X,'INCOME',7X,'UNITS', 7 7X,'YEARS OLD',4X,'HOUSING',5X,'DISTRICT',5X,'HOUSING'/)		
	C			
0179	C	2300 FORMAT('1',42X,'CENSUS TRACT POLLUTANT CONCENTRATIONS -- INPUT' //1X,16A4,4X,16A4// 1 3X,'NUMBER',4X,'POLITICAL',5X,'CENSUS', 2 5X,'POLLUTANT CONCENTRATION', 3 9X,'NUMBER',4X,'POLITICAL',5X,'CENSUS', 4 5X,'POLLUTANT CONCENTRATION', 5 12X,'JURISDICTION',3X,'TRACT', 6 4X,'(MICROGRAMS PER CUBIC METER)', 7 15X,'JURISDICTION',3X,'TRACT', 8 4X,'(MICROGRAMS PER CUBIC METER)'/)		
	C			
0180	C	2400 FORMAT('1',50X,'CENSUS TRACT PROPERTY VALUE BIDS'//1X,20A4// 1 8X,'NUMBER',11X,'POLITICAL',12X,'CENSUS',11X,'MEDIAN', 2 11X,2('PROPERTY',10X),'DIFFERENCE' 3 24X,'JURISDICTION',10X,'TRACT',11X,'PROPERTY', 4 11X,2('VALUE',13X),3X,'IN' 5 63X,'VALUE',14X,'BID',15X,'BID',14X,'PROPERTY', 6 81X,'BEFORE',12X,'AFTER',14X,'VALUE', 7 81X,2('SHIFT',13X),2X,'BID'/)		
	C			
0181	C	2500 FORMAT(5X,2A4,A1,F13.0,F13.0,F14.0,F11.0,F12.0,F14.0,F13.0,F11.1, 1 F12.1)		
	C			
0182	C	2610 FORMAT(1X,I6,I12,I12,'.',I1,F19.2,I22,I12,I12,'.',I1,F19.2)		
	C			

Figure E.6-6. Program Listing for ASSIGN Subprogram, Assignment Module (Cont'd)

FORTRAN IV G LEVEL	19	ASSIGN	DATE = 71189	08/10/21
0183		2620 FORMAT(1X,16,112,112,F21.2,122,112,112,F21.2)		
	C			
0184		2710 FORMAT('0',111,8X,6A4,2A4,F17.0,F18.0,F18.0,F19.0)		
	C			
0185		2720 FORMAT(20X,6A4,3A4,F13.0,F18.0,F18.0,F19.0/)		
	C			
0186		2810 FORMAT(1X,111,119,119,'.',11,F17.0,F18.0,F18.0,F19.0)		
	C			
0187		2820 FORMAT(1X,111,119,119,F19.0,F18.0,F18.0,F19.0)		
	C			
0188		2910 FORMAT('0',111,10X,2A4,2A4,F31.0,F18.0,F18.0,F19.0)		
	C			
0189		2920 FORMAT(22X,2A4,3A4,F27.0,F18.0,F18.0,F19.0)		
	C			
	C			
0190		END		

Figure E.6-6. Program Listing for ASSIGN Subprogram, Assignment Module (Cont'd)